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THE ARISTILLUS TEST FOR PLANETARY DEFINITION.

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Apparently the first person to see the double canal on the outer slopes of Aristillus after its existence had been announced in POPULAR ASTRONOMY, Report on Mars No. 5, was Professor Aitken, making use of the 36-inch telescope of the Lick Observatory. He accurately describes the appearance of the outer canals, but after a year's trial, has written me that he had given up as hopeless any attempt to see the duplication within the crater. This is doubtless on account of the large aperture of the telescope, which would require marvelously good seeing in order to be used to advantage for such a purpose. The same reason probably explains the failure of Professor Barnard to see it, who wrote me he should try to do so.

The first persons to confirm the resolution of the canals within the crater were Dr. Lowell and Mr. E. C. Slipher as we have seen in the very excellent set of drawings published in the February number of POPULAR ASTRONOMY. Figures 2 and 4 are the most complete for the outer slope, and show a number of fine canals, some of which are more difficult than the interior double itself. For comparison a sketch (Plate XIII) made here at Mandeville is given which was drawn 1915 October 19, colongitude 50°.4. The region of the little cross below the inner canal, contains some of the more delicate features.*

There are three statements in Mr. Slipher's paper and three only that seem to require comment. One is that the canal varies in breadth and density in different portions of its length. This is true only when it is

* See also The Double Canal of the Lunar Crater Aristillus. POPULAR ASTRONOMY 1914 **22**, 570.

fading out, and becoming confused with the shadows towards sunset. This is very well shown in his Figures 3, 4, and 5. When the canal is forming, as in his first, and in Dr. Lowell's drawing, the canals are straight, narrow, and perfectly uniform in breadth, very like indeed some of the finer canals visible at the present time upon Mars. Towards noon, that is at full moon, the canals darken and broaden, as is shown in his Figure 2; indeed they soon broaden so much that the space between them becomes practically filled up. Mr. Slipher's second statement is that the canal disappears for a few hours before and after the time of full moon. This is precisely what would happen, and what would be expected to happen if the canal were due to shadow. Indeed this statement would be of the utmost importance if it were true. Unfortunately for that explanation however it is not true. Indeed the exact reverse occurs, as anyone who is interested in the matter may see for himself even with a 3-inch telescope, since at this time the canal becomes very conspicuous where it crosses the crater's rim.

Between the time that the Sun crosses the meridian of a crater and the time of full moon shadows within it are geometrically impossible. The sun crossed the meridian of Aristillus this past March at $18^{d}\ 12^{h}.0$ E. S. T. The moon was full March $19^{d}\ 0^{h}.4$. For these twelve hours the crater was necessarily shadowless as seen from the Earth. Observations made on the evening of March 18 after midnight showed the canals particularly broad and intensely black. Therefore they could not be due to shadow. This particular observation had of course been made here many times before, since it is a perfectly obvious precaution which is always taken to avoid the confusion of patches of vegetation with shadow. It is only mentioned here now in order to give a recent concrete contradiction to the statement in question. The canal was also easily seen in the 3-inch finder with a magnification of 90. Since it was conspicuous both inside and outside the crater rim at this time, while for a few days at sunrise it is certainly invisible outside, and for a few days towards sunset is certainly invisible inside the rim, it is clear that it cannot owe its existence in any way to shadow. The third statement that the canal crosses the floor of the crater is also incorrect. It originates about half way up the interior north-western wall, and instead of going down onto the floor, then proceeds northwesterly up over the rim.

These corrections are of little consequence, as I believe no one at the present day attributes the canals and variable spots visible at full moon to shadow, but they are refuted here simply because they accompany a plate containing some very excellent drawings of a very interesting object, and for that reason it seemed desirable to correct them. Up to date it is believed that Dr. Lowell, Mr. Slipher, and the

writer are the only persons who have succeeded in dividing the interior canal. In a recent letter from M. Jarry Desloges he states that it is being observed from his station at Setif in northern Africa, and since the atmospheric conditions there are clearly of very high quality, there is little doubt but that the division will be accomplished there also.

While it will be clear from what has preceded that this is a pretty difficult test of planetary definition for the average observatory, and one which it is hopeless to attempt to achieve with an aperture of much less than 8 inches, or a magnification of less than 300, yet it must be recorded as the writer's opinion, that it is doubtful if any duplication on the planet Mars will prove as easy as this lunar canal. It is true the writer has not seen any double canals as yet upon Mars, and for that reason still remains a little skeptical about their existence, especially since the past two oppositions are precisely the ones when according to Schiaparelli they should be most readily visible. He can state however that it is certain that neither at this opposition nor at the last has there been any double canal on Mars as readily visible as that seen in Aristillus.

A few of the Martian canals such as Thoth, Nilosyrtis, and Cerberus are obviously more conspicuous than those on the outer slopes of Aristillus, when we view first one and then the other under similar conditions. On the other hand the great majority of the Martian canals are much fainter, and their duplication would certainly be more difficult. Therefore it is plain that no observer whose equipment and atmosphere make it impossible for him to divide the interior canal in Aristillus has any right to express an opinion as to the existence of double canals on Mars.

Under favorable conditions the resolution of the canal in the interior of Aristillus is always possible between colongitudes 35° and 65°, and between 110° and 140°. It is therefore visible on from four to six nights out of every lunation, and should any other observer succeed in seeing it, I hope that he will inform me, since it is very desirable to know at what other observatories in the world besides at Mandeville where it was discovered, and at Flagstaff where it was confirmed, the really best atmospheric conditions are to be found.

Mandeville, Jamaica. B. W. I.
March 22, 1916.

THE MOVEMENTS OF THE MOON

J. PERCY JOHNSON.

Certainly, the Moon is the most lovely orb of heaven, and richly deserves the title bestowed upon her by the poets—"Queen of the Night." There is no other heavenly body, with the possible, but doubtful, exception of the Sun, which is subjected to more observation by "the man in the street," and there can be little doubt that this is chiefly due to her peculiar beauty as she presents her varying phases to our view, and to the pale soft loveliness of a moonlit landscape, which is more entrancing than the warmth and brilliance of one illumined by the glory and splendour of "King Sol" himself. Who has not beheld with pleasure the slender crescent of the young Moon in the evening sky, or gazed in rapture on the heaving waters of the ocean glistening under the silvery moonbeams?

The Sun may be the grandest, the most important object in the Universe so far as the inhabitants of the Earth are concerned, in their dependence upon the beneficence of His Majesty's rays; the great nebula in Orion may be the most awe-inspiring spectacle astronomers have ever looked upon; Saturn, with its wonderful rings, may be the most unique revelation of the telescope; but—upon this, I think, all are agreed—the gentle loveliness of our faithful satellite, the Moon, is unequalled in the realms above.

In which of her many changing aspects does the Moon most delight the eye of man? Is she most lovely of all when seen in the beautiful western sky at sunset,—an exquisite crescent with "the Old Moon in her arms,"—or when serenely "sailing" high in the heavens, 'mid the fast flying clouds, she shines o'er land and sea, investing every scene with a beauty all her own, or is the great, golden Harvest Moon of autumn, rising night after night in the north-eastern sky about the time of sunset, the loveliest of all the lunar phases?

Who shall say?

In addition to this wealth of beauty, manifest to the most casual observer of Nature, the Moon has many attractions which merit much attention, and which arise mainly from the fact that she is our nearest neighbour, and can be subjected to a closer scrutiny than can any of the other denizens of space.

To the amateur astronomer possessed of a telescope, the Moon is certainly the most beautiful of celestial objects, and he can sit for hours at his instrument, reveling in the unsurpassed glories of the lunar landscape. To one who looks at the Moon telescopically for the first time, the sight is a never-to-be-forgotten one. The jagged line of mountains, dividing day from night, catching the sunlight on their top-most peaks, looks like a row of snow-white crystals, or shining jewels, and never fails to draw forth exclamations of surprise and admiration. The strong contrasts of light and shadow are a never-ending source of delight and wonder,—the shadows streaming across the plains, and revealing in exaggeration the contour of the mountain ranges.

The Moon's interest, however, lies not only in her telescopic appearance, a description of which, unfortunately, cannot be included in the present article. With the single exception of the Sun's apparent movements athwart the heavens, the Moon's varying position among the stars, with the accompanying change in her phase of illumination, is the most obvious and striking of all astronomical phenomena, and one which has attracted the notice of man from times of the remotest antiquity. Although the earliest records extant in this connection are merely the expression of a primitive wonder and simple nature-worship, they are exceedingly interesting, and deserve more than the passing reference here made. They take the form of hieroglyphic inscriptions which the Egyptian races, of probably 6,000 years ago, left on their temple walls, showing us that the Sun, Moon, and stars, were then regarded with a seriousness we would do well, to a certain extent, to imitate. At that early period in the history of mankind, about which much might be written, the stage of thought was primarily that of worship, as is shown by the evidence of the deification of the various celestial bodies to be found on every hand in the majestic ruins of the vast and mighty buildings in that strange land on the banks of the Nile.

There is also ample evidence, however, that the utilitarian point of view was not neglected,—indeed, it was more important than we are apt to realize in these days of calendars. This is conclusive in the case of the Sun, whose variations were sedulously watched by the priests, both for religious and mundane purposes, and it is certain that the convenient division of time marked by successive lunations would direct an equally scientific attention to those of the Moon. In one of the inscriptions referred to, the waxing Moon is typified with that charming simplicity which always characterizes these pictorial writings, but which very simplicity often baffles the best brains for an explanation. It is known as "The Square Zodiac" of the chief temple

of Denderah, and shows the moon-god at the top of a flight of fourteen steps, which symbolize both the Moon's increasing phase, and the number of days between "New Moon" and "Full Moon"! In another representation, the god is divided into fourteen pieces to illustrate the phenomenon of the waning Moon!

In parenthesis, it may here be allowable to emphasize the better perspective of awe and wonder which obtained in those far off days, when even the succession of day after night was looked upon with feelings of doubtful confidence, than does with the majority of people today. Although it would be foolish to compare the vastly superior knowledge possessed by the public in general, and astronomers in particular, in the twentieth century, with that superstitious regard held by the ancients, it is, at the same time, that very excellence of the learning of today which is responsible for the careless indifference of the many too fundamental facts of nature.

These may not be of so recent discovery as, for example, the so-called "canals" on Mars, and may not be so sensational to the popular mind, but they are, nevertheless, among the most impressive things in the Universe, fit food for the deepest thought and meditation.

All the heavenly bodies, Sun, Moon, planets, and stars (and comets too, when they happen to be visible) daily perform an apparent revolution round the earth, due to the latter's diurnal rotation on its axis. The general ignorance which prevails respecting this motion of the stars is remarkable, but it will come as a shock to many readers when it is stated than many persons are entirely unacquainted with the Moon's regular performance of this apparent daily motion. (The word "apparent" is used to signify that the movement is not real on the part of the Moon, but is similar to the apparent motion of objects seen from the window of a traveling train). The extent of their knowledge seems to be confined at the most to three weeks out of every month. What becomes of our satellite during the remainder of each period, remains with them as great a mystery as the Sphinx, and, it might be added, as far as they are concerned, matters less! Surprising as it may seem, the writer has heard the greatest wonder expressed by otherwise intelligent persons at what should be the familiar sight of the Moon in her First Quarter in the afternoon sky. Such complete indifference to natural phenomena, whether "in heaven above.....in the earth beneath, or in the waters under the earth," is not justifiable. It is our duty as intelligent creatures inhabiting this planet to take reasonable notice of what is taking place around us.

Let us, therefore, attach our interest to the common, but beautiful spectacle of the crescent Moon in the evening sky at sunset, watching night by night her progress among the twinkling stars, and try to

realize something of the feeling which animated those who carved that simple note on the temple stone at Denderah, which will endure when this printed page, and the material bodies of those who read it will have passed into oblivion.

In the first place, it is interesting to discover how soon the Moon first becomes visible after the time given in calendars as that of "New Moon." Previous to this, although the Moon is in the immediate vicinity of the Sun, she is lost in his superior lustre, and we are apt to forget her presence until we are apprised of the fact by her withdrawal to a sufficient distance to permit her illuminated rim to be glimpsed. Theoretically, the completely dark "New Moon" should be of brief duration, and quite a degree of enthusiasm may be introduced into monthly searches to secure earlier detection of the exceedingly delicate crescent she presents on her first appearance after emerging from the overwhelming brilliancy of the great luminary. Under the conditions of such early observance, she will be disclosed in the evening by the diminution of the Sun's powerful light, but, following the example of her grand-parent, she sets almost immediately. Carried by the diurnal rotation of the heavens beneath our feet, she rises soon after the Sun the next morning, and will doubtless be apparent in the sky throughout the day. It will be observed that the convex surface of the crescent is presented to that part of the sky in which the sun is situated. It is surprising how many artists spoil what otherwise might be good pictures by neglecting such an observation as this, and erroneously depicting the concave side turned towards the place of sunset, thus betraying their ignorance of the source of the borrowed radiance of the "Lamp of Night."

Once again the Sun sinks in the golden west, and the shades of evening commence to fall. As twilight deepens into dusk, the Moon, now appreciably advanced in phase, and occupying a position further to the east than that of the previous evening, though sinking in the heavens, lingers yet awhile, an object of rare beauty and delight, hanging in the vault of heaven like some phosphorescent ball of liquid light set in a silver bowl.

"The Old Moon in the New Moon's arms—"
so familiar! so charming!

It may be noted in passing that the bright crescent often seems to belong to a distinctly larger body than the remainder, which accentuates the appearance above referred to, especially when the Moon is "on her back," to use a popular expression.

This is an optical illusion, due to irradiation, by virtue of which, a light body projected on a dark ground appears to be larger than it is.

In the spring of the year, by reason of the oblique angle at which our satellite's path meets the horizon, the young Moon remains in the sky, many hours after sunset; but eventually, whether sooner or later, as our hemisphere of this ponderous earth turns over for its night's repose, the horizon rises up and cuts her off from view, depriving us of her reflected rays, which, although so mild and gentle, have hidden the full glory and splendour of the starry firmament.

A similar sequence of events takes place during the next twenty-four hours, with the result that the moon is discovered still further to the east, and more fully illuminated. When she happens to be near a star this motion, which is known to astronomers as "direct" motion because it is the Moon's real movement as distinguished from that "apparent" daily rising and setting motion, is easily noticeable in the course of a couple of hours. The distance between the Sun and Moon is thus steadily increased by this persistent movement to the east, and the illuminated portion of the latter's disc is constantly directed to the former's. When about seven days old, the Moon is in her "First Quarter" and about the time of sunset is on the meridian,—the line which passes through the zenith and the north and south points of the horizon. The gibbous phase is now entered upon, and every night the Moon continues her journey to the east, until "Full Moon" is attained, when she rises at the time of sunset, and is on the meridian at midnight. Of course, when it is said that the Moon is further to the east, it must be understood that it is so at the time of our initial observation, which in this case was sunset, as the daily rising and setting motion, due to the Earth's own rotation, carries it through all positions in the course of a day.

The phase now decreases, and it will be seen that the illuminated part has "faced about" and is now directed to the eastern sky. When she has reached her "Last Quarter" the Moon does not rise till about midnight and at sunrise is on the meridian in the morning sky. During the next seven days she approaches closer and closer to the Sun until a very fine crescent is attained, when she is seen only in the strong light of dawn in the east. Then she is lost in the Sun's rays, to emerge shortly afterwards as a brand "New Moon" in the west!

This is the monthly cycle of the Moon's changes, and although some may smile at such a laboured description of what they think is of such common knowledge, the writer is content to let it stand in view of what was remarked in the early part of this article. Very little consideration of the above observations will convince one that the Moon's light is not an inherent property, but that she is a dark, globular body reflecting the Sun's rays, whilst the only explanation of the "backward" motion from west to east (which truly is "real" and "direct" motion),

which has been distinguished from the daily movement from east to west (which truly is only "apparent" and "retrograde"), is that the Earth's satellite is revolving round its primary in a period of about four weeks.

According to Professor Newcomb both these facts have been known from the earliest times.

That her light should be so white need occasion no surprise when one thinks of the pure whiteness of the clouds, which at other times, when not reflecting the solar rays, are so dark and forbidding. It has been variously estimated, however, with regard to the intensity of the lunar beams, that from 300,000 to 600,000 "Full" Moons would be required to produce the degree of illumination experienced by the earth on a bright summer's day!

Let us now consider more closely the period taken by the Moon to complete her orbital motion. Subsequently we shall deal with the dimensions of that orbit and certain variations in its form, which, though minute, are of great interest and importance, and were known thousands of years ago.

It has been mentioned that the interval of time between two successive "New" Moons is about four weeks. Actually, the average period is 29½ days, but this does not represent the time taken to make a complete circuit of the Earth. It is too great, for this reason: The Sun, like the Moon, has an independent movement apart from the daily rising and setting motion, which carries it from west to east. This is, however, not a "real" motion on the part of the Sun, as was the Moon's, but an apparent one due to the Earth's yearly journey in space and consequent projection of the Sun on every part of a great circular belt on the background of stars, known as the Zodiac. That is to say, the Sun has a "backward" (direct) movement in the sky like the Moon, but a much slower one, which only carries it through in a year, what the Moon can accomplish in a month. Therefore, when the Moon arrives at that point in the great pathway of the stars at which she was last "new" she has circled the Earth completely, but the Sun has apparently moved further to the east, and it takes the Moon a little over two days to "catch up" and become "new" once more.

The first of these, the true period, because it may be referred to the position of the Moon in the stars, which for this purpose may be regarded as forming a changeless background or dial, is termed the "sidereal" month. The second, or interval between two similar phases is called the "synodical" month. The length of the sidereal month is 27d., 7h., 43m., 11½s., whilst the synodic month is, as has been mentioned, 29½ days. There are, however, several minute variations which render this statement liable to slight modification, as will afterwards appear.

The Earth's annual motion round the Sun, we have said, causes the latter to appear in various parts of the background of stars which is situated at an infinitely remote distance in comparison to those of both Sun and Moon. The constellations in which the Sun successively appears (or indeed would do so if his light did not hide them) are the well known twelve signs of the Zodiac—Aries, Taurus, Gemini (The Ram, the Bull, the Heavenly Twins) etc., and its actual path which runs through this belt of the Zodiac is called the "Ecliptic". Its position is obviously determined by the direction of a line from the Earth to the Sun, and continued to the starry dial. As the Earth proceeds on its annual voyage round the Sun, this imaginary line will sweep round in a plane, which is "the Plane of the Ecliptic", or the plane of the Earth's orbit. This plane is marked out then by the Sun's path in the sky, which can be accurately marked down on a map of the stars.

Now the Moon marks out its own track in the sky, and this can also be marked on the chart of stars. It is found on so doing that the Moon's path cuts the Sun's path or Ecliptic at an angle of five degrees.

Therefore, part of its monthly journey is above the plane in which Earth and Sun are situated, and the remainder is below that level. That point at which the Moon commences to rise above the Ecliptic is called the "ascending node," and that at which it begins to descend below it, the "descending node." It is apparent that once a month when the Moon is "new," it must occupy a position somewhere between the Earth and the Sun, and it is further quite clear that if she were *directly* between the two, or *in the Plane of the Ecliptic*, she would "eclipse", or interrupt the Sun's light.

We have seen that the Moon is in the plane of the Earth's orbit at two points only, the nodes, so that when an eclipse occurs, it is certain that one of these nodes lies in a position exactly between the Earth and the Sun. If this node were fixed in that position, an eclipse would occur regularly every month at "New Moon," but as eclipses are not of such regular occurrence, it follows that the Moon when occupying a position intermediate between the Sun and Earth, it is generally a little too high above the Plane of the Ecliptic, or a little too low down below it to be in an absolutely straight line between the two and cause an eclipse.

It is perfectly plain, therefore, that the position of the nodes is not constant,—in fact, it has been found that these points are gradually changing their positions, and that in about 18½ years they make a complete revolution of the Moon's orbit. A good idea of the effect of this on the plane of the Moon's orbit can be obtained by spinning a plate on the ground. Just before it is about to collapse flat on the floor it will present a fair representation of what is taking place, each

"wobble" corresponding to an 18½-year revolution of the nodes. Naturally the recurrence of eclipses of the Sun and Moon depends upon this phenomenon, as an eclipse of either of these bodies can only happen when the Moon is at one of its nodes or a certain definite distance thereof, (1) at "New Moon" and (2) at "Full Moon." Taking the case of solar eclipses:—If no other circumstance had to be taken into account, an eclipse could happen only once in 9¼ years, or the time taken for a node to make half a revolution and occupy the position previously held by the other node. While this backwark movement of the nodes, which amounts to one and three-fifths degrees a month, is taking place, however, the Sun's position is moving forward (W to E) at the rate of 30 degrees a month, so that at the end of that time the node is removed from the Sun's position thirty one and three-fifths degrees, and in five and three-fifths months 180 degrees will separate the two positions. This means to say that the other node will now be in front of the Sun, and the conditions for an eclipse again occur, so that two eclipses must occur within six months. We have assumed, however, that the node must be directly between the Sun and the Earth. This is not quite true, as the Sun and Moon are not mere points, but have a magnitude, so that if the node is sufficiently near to permit their respective disc edges to overlap a partial eclipse will be visible, whilst the magnitude of the Earth allows an observer to move about to various vantage points and still further increase the frequency of eclipses of the Sun. Indeed, eclipses of the Sun are of more frequent occurrence than eclipses of the Moon, *if the observer is always able to be on that part of the Earth from which the solar eclipse is visible*, but if he is not able to move about in this way the lunar eclipses become the more common, for, whilst the belt of Earth permitting observation of the former is narrow and is continually varying its position, the latter, when visible, is so from every part of a whole hemisphere of the Earth. From what has been said it will be seen that, far from an eclipse happening only once in 9.3 years, a regular series of eclipses will be possible under the conditions laid down, but that after 18.6 years this series will start all over again and the eclipses will all be repeated at successive intervals of time similar to those in the previous series.

The Chinese of two thousand years ago recorded eclipses, but not systematically, whereas the Chaldeans were well acquainted with the period we have been discussing, which they termed the Saros, and were thus able to predict the recurrence of eclipses more or less truly.

This period, however, is subject to slight modification owing to small variations which have not been dealt with, and it was subsequently improved upon in 432 B.C. when the Metonic Cycle was introduced

with a much smaller degree of error, whilst in 330 B. C. Callipus made a further improvement by which all eclipses, and the day on which they would occur, could be predicted for years to come. All these results were solely from observations of eclipses and it was reserved for Hipparchus (190-120 B. C.) to discover the dimensions and nature of the Moon's orbit and the revolution of the nodes in 18⅔ years,—remarkable achievements 2,000 years before the invention of the telescope!

The Moon's distance, this wonderful astronomer found, by parallax, to be 59 times the radius of the Earth,—a practically correct result, and he also rightly determined the inclination of the Moon's orbit to the Ecliptic to be five degrees.

The problem of the Moon's distance is more suitable for inclusion in an article dealing especially with the measurement of planetary distances, and will therefore not be dealt with in the present article. Angular measurements on precisely similar principles to those underlying the work of surveyors have revealed that our satellite is situated at a mean distance of 238,840 miles. Such measurements conducted when the Moon is in various parts of its orbit show that although viewed from the point of view of its magnitude the orbit is practically circular, (as is also shown by the fact that the Moon's apparent diameter is subject to no great variation), it is not exactly so. The Moon occasionally retreats to a distance of 259,600 miles, whilst at other times her distance is reduced to 221,000 miles.

Hipparchus, by comparing the intervals between eclipses, discovered that the Moon moved faster in some parts of her orbit than in others, and was so led to infer the ellipticity of her path.

Other variations of the Moon's motion may be briefly mentioned. The two points at which the Moon is least and most removed from the Earth (perigee and apogee), by virtue of orbital eccentricity, are found to have a motion opposite in direction to that of the nodes (direct, therefore) which carries them completely round the orbit in 8.8 years. This is caused by the disturbing influence of the Sun, which also has another effect, discovered by Tycho Brahe, namely, that of retarding the Moon's velocity, so that the sidereal month, which, as has been explained, is the true period of the Moon's revolution round the Earth, is an hour longer than it would be if the Sun could be imagined to be absent.

The Earth's path round the Sun is also elliptical however so the Sun's distance is a variable quantity. His retarding influence is therefore variable accordingly, *and although the net result is as stated above*, the Moon gets ahead of or falls short of her mean position (i. e. the position she would occupy if the Sun had no disturbing effect)

according as the Sun's distance and influence is lesser or greater, by an amount known as the "annual equation." Now although all these perturbations were explained by the great and immortal Sir Isaac Newton on gravitational principles, there are others of an exceedingly minute, but none the less definite character, which mathematical science is not yet in a sufficiently advanced condition to account for—and that is saying a good deal. Although in the present article the writer has left the Moon's telescopic appearance strictly alone in order to avoid undue length, certain facts must be noted in connection with the movements of our attendant satellite. In the first place, the Moon always presents the same hemisphere towards the Earth,—three sevenths of the Moon's surface has never been seen by man, and never will be.

The reason for this is, not that the Moon has no axial rotation, but that the period of that rotation is the same as that of her revolution round the Earth. In other words, in going round the earth once, the Moon turns on its own axis once. Many people experience a difficulty n appreciating this fact, which may be readily understood by the following performance:—

Regard some object in the centre of a room, such as a table, as the Earth, with oneself to represent the Moon. Move around the table once, keeping the face always turned towards it. Now, although one has never turned the back towards the table, it is evident that not only has one encircled the same, but that every part of the room has been faced in turn. That is to say, whilst performing the motion of revolution, a concomitant one of "axial rotation" has also been performed. This is exactly analogous to the case of the Moon.

It has been mentioned that only three-sevenths of the Moon is visible from the Earth, which of course means that *more than one half is visible*. It is now to be seen how the extra little bit (one-fourteenth) is caught sight of.

It is due to three causes, viz., longitudinal, latitudinal, and diurnal libration! In the language of astronomers, how terrifying all that seems. In reality, it is quite simple. Libration in longitude is an apparent swinging of the Moon to the E and W and it is brought about owing to the facts that while the Moon's rotation on its axis is steady and constant, its movement in space is unequal, as we have seen, sometimes it goes quicker than at others. When it goes quickly, we catch a glimpse round one side, when it goes slowly we get a look just a little tiny way round the other side. Libration in latitude is an apparent swinging of the Moon to the N and S. This is brought about by the two circumstances that the moon's orbit is inclined to the ecliptic at an angle of five degrees, and that her axis is inclined to her own orbit

a further 1½ degrees, the effect being that the Moon is now tipped with the N pole 6½ degrees towards us, and when at the opposite side of her orbit, she has her S pole tipped 6½ degrees towards us.

Diurnal libration adds to longitudinal libration in that we see further to the east and west of the Moon than we would do without it. It is due to the Earth's own daily rotations, which carries an observer to and fro enabling him to extend his views to the right and left of the Moon's face.

It will probably have been noticed by most readers that when, in summer, the nights are practically never dark, and there is no great need for the Moon's light, that is the very time she attains her least elevation above the horizon, and therefore sheds the least light; whereas, when the nights are long and dark, she attain her greatest elevation and we receive the best possible benefit from her rays. "Pat" was fairly near the truth, accordingly, when he replied to the question as to whether he preferred the Sun or the Moon, that the Moon met with his preference, as she shone in the night when she was needed, but the Sun shone in the day, when anybody could see!

The reason for the Moon's varying summer and winter altitudes may be seen if we consider her when "new" and when "full". When "new" she is close to the Sun, and in midsummer, the Moon's greatest elevation is attained when the Sun is highest in the heavens, at midday. Like the Sun, the Moon has by far the greater part of her path above the day-time horizon. When the Moon gets round to the opposite side of her orbit, and to the "full" phase, it is the remaining and smaller section of her path which is raised above the night-time horizon, and she therefore reaches no great elevation. In winter, the Moon when "new" is again close to the Sun, which is this time in its lowest position in the heavens. When the "Full Moon" is reached she is in the larger section of her orbit and at midnight is high in the sky. In effect, the Moon when full is always in that part of the sky which will be occupied by the Sun in six months' time, and it may have been noted—what never fails to strike the writer—that on a bright moonlight night in winter, the shadows of a landscape produce the impression of a ghostly summer scene at mid-day!

The last subject of remark will be the "Harvest Moon." In the northern hemisphere of the Earth, the "Harvest Moon" is that Full Moon which happens nearest to September 23rd, the date of the autumnal equinox.

Its peculiarity is that it rises for several successive nights at practically the same time, and is supposed to be on that account a help to harvesters.

The Moon has not ceased to perform its persistent motion from W to E, which has been discussed, by virtue of which it is 51 minutes later arriving at the meridian every night. That movement continues the same as before, but its effect in retarding the rising hour of the Moon is nullified because at the time of the equinox the path of the Moon cuts the horizon at a very oblique angle, so that the movement is almost horizontal and carries it very little further below the horizon for several nights.

A great deal more might be said about our interesting satellite. Her wonderful telescopic aspect, her mountain ranges, plains, craters, rills and rays, her questionable influence on the weather and on disease, her control of the tides,—all these might be dealt with, but each would require an article by itself.

If readers are induced to look with more interest on the calm and peaceful Moon, and think with wonder of the marvelous multiplicity of the variations of her movements in adjustment to grand and simple laws of gravitation then this article will not have been written in vain.

Douglas, Isle of Man.
10 Strand street.

OBSERVATIONS ON JUPITER AT THE OPPOSITION 1915.*

EDISON PETTIT.

The following observations on Jupiter were begun with the Yerkes 40-inch telescope and completed with the Washburn college 12-inch telescope and position micrometer. The observations were made: (1) To determine the rotation period in various latitudes where markings of definite character might be found; (2) to determine the polar compression; (3) on the great red spot; (4) to measure the diameters of the satellites; (5) to determine the character of any markings on the satellites.

General Features.

From twenty five observations a map in Mercator projection was drawn as shown in Figure 1. This takes System II of the Ephemeris as a basis of the longitudes. The quadrant from 180° to 270° was not well observed. Since the planet was near the equinoctial, observations

* Read before the Kansas Academy of Science.

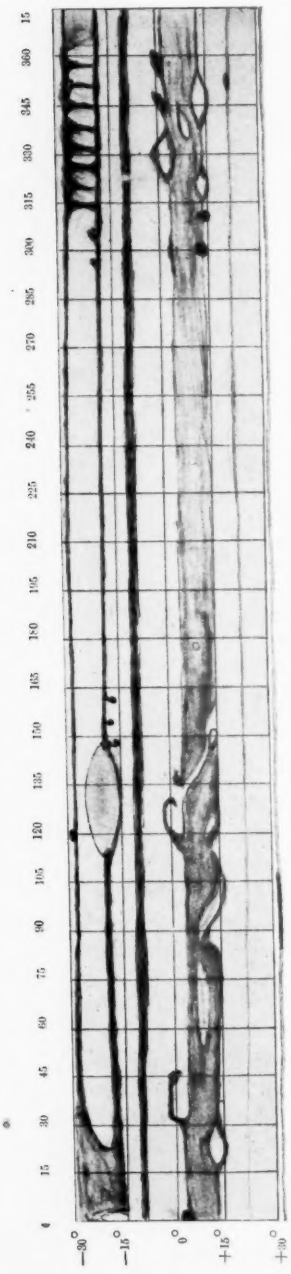

FIGURE 1.

were confined to positions near the meridian. Powers of 750 and 1000 were used on the 40-inch, and all observations with the 12-inch were made with power of 1000. Very clear weather during October and November greatly facilitated observation. Especially clear weather was taken advantage of to measure the satellites which otherwise flared too much.

Almost all the surface features lie between the 30 degree parallels of latitude. Plume-like markings were a quite prominent feature. A peculiar marking was observed on many nights in the southern band longitude 300° to 360°, latitude −15° to −30°, like a grove of trees. Attention is especially called to two small dark spots, the following one in longitude 309°.8, latitude 15° north. This latter is especially adapted to the determination of the rotation period, being small and round and of considerable depth of color. Its actual diameter is 2100 miles, about that of the Moon.

A faint line running around the planet in latitude 32° north is widened to a short thick band on longitude 85° to 105°. This is also well adapted to the determination of the rotation period. The white spots in the neighborhood of longitude 345° were brilliant and in general of a lemon shape.

The Rotation Period.

In measuring the rotation period both transits over the central meridian and elongations of the marking were observed. For the transit observations the double value of the equatorial diameter was measured as usual, and the micrometer set to ¼ this value minus ½ the wire correction. As the marking approached the central meridian it was tested by setting first the right then the left wire tangentially till the eye was

satisfied that the central meridian had been reached and the time recorded to the nearest tenth of a minute. The elongation measures were reduced to the time of central transit. The reductions show that the elongations will give as accurate values of the rotation period as the transits if the seeing is good enough to permit rapid measurement.

From an elongation of the round spot longitude 309°.8 latitude 15°.0 north on September 21st and a transit of October 29th the value $T = 9^h\ 55^m\ 22^s.16$ was obtained. From transits of the black band longitude 82° to 105°, latitude 32°.0 north on October 26th and November 19th, $T = 9^h\ 55^m\ 40^s.76$ or an acceleration of $1^s.1$ per degree of latitude in this region.

The Polar Compression.

Twenty-five observations were made for the polar compression of which ten were rejected on plotting the residuals. From the fifteen remaining the value $1/17.4 \pm 1/270.3$ was obtained. This is a probable error of 6.4%.

The Great Red Spot.

The Great Red Spot was quite distinct at times, showing a dull brick red color. Its measured position was longitude 131°.7, latitude 23°.0 south, length 29273 miles. A peculiar group of plumes follows it. The ends of the spot had quite sharp points.

The Satellites.

On two nights the images were quite free from flaring. The means of the measures are:

I = 2614 mi., II = 2233 mi., III = 3908 mi., IV = 3422 mi.

Markings were observed on III and IV. Attention was especially attracted to III. On two occasions, October 21.419 and October 29.458 C.S.T., a marking was distinctly seen as shown in Figure 2, the angle the straight side of the marking makes with the plane of the planet's equator being 70°. It will be noticed that the time between the observations is nearly equal to the revolution period of the satellite, which seems to indicate that the satellite keeps the same face toward the planet during its revolution and that the marking is always turned away. It will be interesting to see if this feature is a permanet one at the coming October opposition which will be the nearest approach of the planet in twelve years.

Figure 2.

Washburn College Observatory,
Topeka, Kan.
February 21, 1916.

THE HISTORY OF THE DISCOVERY OF THE SOLAR SPOTS.

WALTER M. MITCHELL.

[*Continued from page 218.*]

After reading Galileo's reply to the *Tres Epistolae* as translated through the efforts of Welser, Scheiner wrote a sixth letter* to his patron, dated July 25, 1612. In addition to the customary, "Apelles Latens Post Tabulam", this was signed with the motto, "Ulysses sub Aiacis clypeo." The letter is mainly concerned with the spots. The question of their actual existence, which in Scheiner's mind seems to be still a matter of doubt, is discussed at some length. Two methods of observing, in neither of which a telescope is used, are described, which methods testify that the spots are not caused by the glass. A list of names is given, of observers in Italy and elsewhere who have also seen the spots. Apelles' conclusions regarding the spots are briefly as follows: The apparitions which cause the appearance of spots are not in the eye, nor in the tube, nor in the atmosphere, nor in the heavens far from the sun. They move around the sun at a small distance from it. They are bodies of a thin flat shape, because they diminish their diameter in longitude but not in latitude. They are not to be included among the number of the stars, because their figures are irregular and they vary. They now and then appear in the middle of the sun, and they sometimes disappear before finishing their course. Scheiner compares the observations of Galileo with his own on the same spot, and from their similarity concludes that the spots have no parallax. At the end of the letter he describes an eclipse of the sun which occurred during May 1612. During this eclipse, which was of magnitude seven digits, the moon was surrounded by a luminous aureole. Observing without the telescope, the portion of the moon covering the sun was seen transparent like crystal or glass, and showed the whole of the sun. [!]

* *Gal. Op.* 5, 57.

In a letter to Prince Cesi, dated May 12, 1612,* Galileo informs him that he has completed a letter (the first) in reply to Apelles, and telling Cesi of his conclusions as already quoted (page 90), states that a copy of this letter will soon be forwarded to him. This in fact took place two weeks afterwards. Some months later (September 14) Cesi again wrote to Galileo† offering to print this letter with another on the same subject, (Galileo's second letter to Welser) a copy of which it appears Cesi had received a short time before.

By this time Welser had had the second series of three letters from Apelles printed at Augsburg with the title, *DE MACVLIS SOLARIB. Et stellis circa Iouem errantibus, ACCVRATIOR DISQVISITIO AD MARCVM VELSERVM.....Anno M.DC.XII. Idib. Septembr.* (Plate XIV). A copy of this was forwarded to Galileo on the 28th of September.‡

On the 5th of the following October, Welser acknowledged the receipt of Galileo's second letter.¶ In a letter which has not come down to us, Galileo informs Prince Cesi of his intention of replying to the the *Accuratior Disquisitio.* This reply was sent in the shape of a third letter‖ to Welser, dated December 1st, 1612. In the first part of this letter, which is the longest of the three, Galileo discusses at some length the motion and probable appearance of Venus during transit, which Apelles had "more diffusely explained than in the first letters". He objects to Apelles' proofs by appeal to the common opinions of philosophers and mathematicians, because the opinions of a thousand of these are not equal to the smallest spark of reason, and it is useless to refer new phenomena to the authority of past writers who if they should see the new things, would certainly think otherwise. Galileo then examines the arguments with which Apelles had proved that the spots could not be a part of the sun. Regarding the observations of the spot near the sun's center which required 16 days for transit, and the other in a higher latitude which required only fourteen days, Galileo states that he has made many observations and concludes that all the spots remain on the solar disk for the same space of time, which is slightly more than fourteen days. He criticises the observations, because the spot observed by Apelles was one of a group, and through the irregular changes in the positions of individual spots in a group accidental errors might be introduced. No conclusion can be drawn from a single observation, but only from a comparison of many

* *Gal. Op.* **11**, 296.
† *Gal. Op.* **11**, 394.
‡ *Gal. Op.* **11**, 402.
¶ *Gal. Op.* **11**, 407.
‖ *Gal. Op.* **5**, 186.

such. As a result of comparing a large number of drawings and sketches, some slight differences have been noticed in the times of transit, namely, that the spots crossing near the center of the disk travel faster than those farther away. Galileo then proves with diagrams, that if one assumes that the spots are exterior to the sun and moving in one direction with a common motion, and that Apelles' observations are correct, the spots must need be so far distant from the sun that certain other observed phenomena could not take place. The region in which the spots would have to move is found to be distant from the sun's surface by more than its radius, and on account of the peculiarity of their motions this is manifestly impossible. Apelles' own drawings of spots, accompanying the *Accuratior Disquisitio*, are used to prove that the daily motion of the spots is exactly what it should be if the spots were situated on the surface of the sun and it revolved on its axis.

Apelles had observed the same spot that Galileo had pictured in his first letter, and from the agreement with his own observation asserted that the spot showed no parallax. Galileo objects to this because his observation was not suitable for a comparison, since the drawing simply pictured the spot without indicating its position on the sun, and hence no conclusion could be drawn.

In this letter is the first mention of the "faculae". Galileo calls these small bright spots, and states that since they manifestly cannot be exterior to the sun, and because they show the same motion as the dark spots, the latter must be a part of the sun. He remarks that while Apelles has claimed that the spots are stars, he has taken from them every attribute in which they might resemble the stars. The remainder of the letter contains little of interest regarding the spots. Galileo replies to Apelles' statements concerning the transparency of the moon, whether the earth reflects light or not, the habitability of the planets, etc., etc.

Before this letter to Welser had been finished, the Accademia dei Lincei at a meeting held on the 9th of November 1612, decided that all three letters should be printed by them.* The printing, arrangements for which were made by Cesi, was done at Rome. The progress was slow on account of objections by the Papal Censor to certain passages, and on account of other difficulties; but the publication finally appeared on the 22nd of March 1613.† The choice of a suitable title occasioned many discussions between Galileo and the Lincei; that finally decided upon was, *ISTORIA E DIMONSTRAZIONI INTORNO ALLE MACCHIE SOLARI E LORO ACCIDENTI COMPRESSE*

* Domenico Carutti, *Breve Storia della Accademia dei Lincei.* Roma, 1883. p. 32.
† *Gal. Op.* **11**, 489.

PLATE XIV.

DE

MACVLIS SOLARIB.

Et ſtellis circa Iouem errantibus,

ACCVRATIOR DISQVISITIO

AD

MARCVM VELSERVM

AVGVSTÆ VIND. II. VIRVM

Perſcripta. Interiectis obſeruationum delineationibus.

AVGVSTAE VINDELICORVM

Ad inſigne pinus.

Anno M. D C. X I I. Idib. Septembr.

REDUCED FAC-SIMILE, TITLE PAGE OF *Accuratior Disquisitio.*

PLATE XV.

ISTORIA
E DIMOSTRAZIONI
INTORNO ALLE MACCHIE SOLARI
E LORO ACCIDENTI
COMPRESE IN TRE LETTERE SCRITTE
ALL' ILLVSTRISSIMO SIGNOR
MARCO VELSERI LINCEO
DVVMVIRO D'AVGVSTA
CONSIGLIERO DI SVA MAESTA CESAREA
DAL SIGNOR
GALILEO GALILEI LINCEO
Nobil Fiorentino, Filosofo e Matematico Primario del Serenis.
D. COSIMO II. GRAN DVCA DI TOSCANA.

IN ROMA, Appresso Giacomo Mascardi. MDCXIII.
CON LICENZA DE' SVPERIORI.

REDUCED FAC-SIMILE, TITLE PAGE OF *Istoria e Dimonstrazioni.*

IN TRE LETTERE SCRITTE ALL' ILLVSTRISSIMO SIGNOR MARCO VELSERI LINCEO DVVMVIRO D'AVGVSTA.....DAL SIGNOR GALILEO GALILEI LINCEO Nobil Fiorentino, Filosofo, e Matematico Primario del Sereniss. D. COSIMO II. GRAN DVCA DI TOSCANA. IN ROMA, Apresso Giacomo Mascardi. MDCXIII. CON LICENZA DE SVPERIORI. (Plate XV) The edition was limited to 1400 copies; to half of these was added a reprint of the *Tres Epistolae*, and the *Accuratior Disquisitio* of Scheiner.

At this point it will be of interest to consider the various methods of observing the sun and its spots used by Galileo and Scheiner at this time, as related in their letters.

Scheiner describes the methods of observing employed by him at the close of the first letter to Welser, as follows: *

> 1. The sun may be looked at with impunity in the morning and the evening, when it is clear and not cloudy, it being within a quarter of an hour of the horizon, with an unprotected tube [telescope], but indeed it must be a good one. 2. The sun in any position whatsoever, covered by a fog or a cloud that is fairly transparent, can be seen with a naked tube, without injury to the eyes. 3. The sun, unclouded, in any position whatsoever, can be observed through a tube provided at the place where the eye is applied with a blue or green glass of sufficient thickness, plane on each side, in addition to the concave and convex glasses. This blue or green glass keeps the eye uninjured even at midday; and it is even better, if in addition to the blue glass, if it is not sufficiently thick, there be present in the air a thin cloud of fog covering the sun like a veil. 4. Observations of the sun should commence at the edge, and gradually approach the center, and then pause a moment, for the surrounding brilliancy is too great to at once permit a view of the spots.

From these instructions, it is learned that at an early date Scheiner used and recommended colored glasses. We are informed later in the *Rosa Ursina* that this was suggested to him by his pupil J. B. Cysat.

Scheiner described other methods of observing in the *Accuratior Disquisitio*:†

> The sun, admitted through a round opening, about this size —O— or a little larger, perpendicularly upon a clean white paper or other white surface, shows both itself and all bodies under it, in the same proportions as to distance and situation and number as they are in the sun itself; and in this way I have made a large number of observations.....Again, if you turn a polished mirror (speculam tersum) towards the sun and reflect an image of the sun with the mirror upon a clean paper and a wall at the proper distance, you will see the spots of the sun in number, order, and size, proportionately to the size of the image, as they are in the sun. This method of observing, for which I had sought a long time in vain, I learned from a a very good friend of mine.‡

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* *Gal. Op.* 5, 27.

† *Gal. Op.* 5, 61.

‡ Cysat, most probably.

The last two methods of observing were used by Scheiner as good arguments against those who believed that the spots were due to the telescope itself.

Galileo was of course acquainted with the method of projecting an image with a small aperture, although it is doubtful if he made great use of it. He mentions it in his second letter to Welser:*

> You, seeing in church the light of the sun coming through broken and distant glass, where it falls upon the pavement, place there a sufficiently large piece of white paper, and on it you will see the spots.

The method of observing by projection with the telescope, if we can believe the evidence of Micanzio's letter of September 27, 1631, was first used by Galileo. In the second letter to Welser, Galileo informs us that this method of observing was invented or discovered (ritrovato) by his pupil Benedetto Castelli. There is no mention of the time or place where Castelli communicated this method to his master, but we do know that Castelli was a pupil at Padua.† Galileo's description of the method and the instructions that he gives in the letter to Welser are so explicit and comprehensive that they are well worth quoting, and may indeed serve as a model of clearness and precision which might profitably be emulated by some of our present day writers. He writes to Welser:‡

> I am going to satisfy the promise made to Apelles, namely, as to the method of sketching the spots with great accuracy, invented as I have indicated to him in another letter by a pupil of mine named D. Benedetto Castelli, a member of a noble family of Brescia.....And the method is this. The telescope must be turned toward the sun as if one wished to look at it, and after it has been adjusted and made fast, let him expose a flat white card in front of the concave glass, four or five hand-breadths distant from that glass, so that upon this card will fall the circular image of the disk of the sun, with all the spots that are found upon it, arranged and placed with exactly the same symmetry with which they are situated on the sun. And the more distant the card is from the tube, so much larger will be the said image, and the spots will be represented so much the better; and without any errors all will be seen, except many little ones which could hardly be seen even by looking through the tube with great fatigue and danger to the sight. In order to draw them correctly I first describe a circle of suitable size on the card, and then varying the distance of the card from the tube, I find the exact position of the card at which the image of the sun enlarges itself to the size of the drawn circle, which also serves as a guide and standard for keeping the plane of the card true and not inclined to the luminous cone of rays which comes from the telescope: because when it is inclined the section becomes oval and not circular, therefore it does not adjust itself to the circle drawn upon the card, but inclining the card more or less

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* *Gal. Op.* **5**, 137.

† Antonio Favaro, *Galileo Galilei e lo Studio di Padova.* Firenze, 1883. **1**, 192; **2**, 382.

‡ *Gal. Op.* **5**, 136.

one easily finds the exact position at which the image of the sun coincides with the drawn circle. When this position has been found, one marks with a pen on the images of the spots themselves, their shapes, sizes, and positions. But it is necessary to proceed skillfully, following the movement of the sun, and frequently moving the telescope, it is necessary to try to keep it well directed toward the sun. This can be determined by looking into the concave glass in which a small luminous circle is seen, concentric with that glass when the telescope is accurately directed toward the sun. And in order to see the spots very clearly and distinctly, it is well to darken the room, closing every window so that no light may enter other than that which comes through the tube, or at least let it be darkened as much as can be, and then let there be placed on the tube a sufficiently large card-board, which will cast a shadow upon the card where one is to draw and which will prevent any light from falling on it other than that which comes through the glasses of the tube. Then it must be noted that the spots come from the tube inverted, in the reverse order to that in which they are in the sun; that is, the right becomes the left, and the upper becomes the lower, because the rays cross each other inside the tube before they pass out from the concave glass. But since we draw them on a surface facing the sun, and then turning toward the sun we should hold the card with the drawing [side] in front of our eyes, thus the surface upon which we first drew is no longer facing the sun but turned away from it, and therefore the right side again corresponds to the right side of the sun, and the left side to the left, whence it remains that only the upper and lower parts are inverted, but turning the card over and causing the upper side to become the lower and looking through the transparency of the card (the drawing being on this side away from the eye) at the light, the spots are seen correctly, just as if we were looking directly at the sun, and in this way they should be exhibited and drawn upon another card in order to have them well situated.

The letter of Fulgenzio Micanzio, previously referred to, is the evidence which leads us to believe that this method of observing was known to Galileo when at Padua. Micanzio writes from Venice:*

> I remember most distinctly that when you had made here the first telescope one of the things that you observed were the spots on the sun. And I could name the place and the point, where on a white card you showed them with your telescope.....

There will be a little question of the method of observing indicated by the wording of this letter, but whether it can be considered as a true account of what actually took place is a different matter, and one which is obviously of high importance. Arago objects† to the evidence of this letter on the ground that if the image had been produced by the object glass alone it would have been too small to show any ordinary spots. If the method described is understood to be that in which both the object glass and the eyepiece were used, Arago demands why Galileo should subsequently state that the method was shown to him by Castelli. In view of what has been quoted above, the objections of

* *Gal. Op.* **14**, 298.

† *Oeuvres* **3**, 275.

Arago are obviously without point. Similarly Wolf* takes the view that the image was projected without the eyepiece.

Neither Carrara nor Favaro are inclined to give great credence to Micanzio's letter in regard to the method of observation. But mere doubt, without some tangible evidence for doubting, is not an argument against Micanzio's veracity any more on this than on the greater question of whether the spots were seen at Padua at all. Practically all competent authorities credit Micanzio's letter in this regard, and it seems hardly just to credit what is implied by the letter as a whole, only to reject a portion of it when there is no real reason for the rejection. The only real evidence for doubt, and this is by no means conclusive, is given by the letter of Maelcote to Kepler, dated December 11, 1612, which has already been quoted (page 88). In this letter Maelcote remarks that although Galileo had shown the spots to him at Rome, he neglected to observe them, fearing injury to his eyes, until he had modified Kepler's device by, "passing the rays through a dioptric tube provided with both its concave and convex glasses and properly extended." Unless Maelcote's memory was bad, which seems hardly probable, this letter indicates that when Galileo showed the spots to him in Rome he used some method of observation other than projection through the telescope. Hence it might be assumed that at this time Galileo was ignorant of the method. But the evidence is not conclusive, for we are not told what method of observing Galileo did use, nor are we told the time of day when the observations were made, which would make considerable difference. Remembering that this method was invented by Castelli, and that Castelli was a pupil at Padua, it is reasonable to suppose that Micanzio's letter is a statement of the actual facts, and that Galileo was acquainted with and employed this method at an early date.

It appears that Scheiner had at first no knowledge of the method, for he makes no mention of it previous to the date of Galileo's letter in which it is described; and hence we are led to believe that Scheiner first learned of it from this letter. Schreiber† on the contrary asserts that Scheiner was without doubt the first to use it, although Kepler may have been the originator. In the *Dioptrice*, Props. 88 and 105,‡ Kepler discusses on theoretical grounds the possibility of projecting the image of an object upon paper by means of two lenses. Scheiner did not have quite the presumption to claim to be the originator of the method, nor is he generous enough to acknowledge who did originate it. In the *Rosa Ursina* he writes:¶

* *Handbuch der Astronomie. Zürich* 1890. **1**, 567.
† *Op. Cit.* p. 12.
‡ Kepler, *Opera Omnia* **2**, 550; 555.
¶ Lib. II, p. 75.

This simple method seems to have been invented simultaneously by learned men in different countries who were occupied with this thing [solar observation].... For I used it a long time before Galileo communicated it to Welser, having learned of it through assiduous and diligent investigation of the sun.

Schreiber gives credence to Scheiner's assertion that he had invented the method independently, even if he was in possession of Kepler's *Dioptrice* at the time; for the two propositions in question could easily have been overlooked. Rather curiously it appears from the undated letter to Wackher* that Kepler had no recollection of his own description of it. Apparently Kepler first learned of the method from Maelcote's letter of December 11th; Maelcote's reference to the method of "passing the rays through a dioptric tube" referring to the propositions in the *Dioptrice*. In his reply Kepler† states that he tired himself in vain because he had removed the eye lens, and only perceived the spots when both lenses were in place and slightly separated.

The Quarrel Between Scheiner and Galileo.

At about the time of the publication of the *Istoria* there began to be heard the premonitory rumblings which were the first indications of the bitter quarrel which was to follow between Scheiner and Galileo. It seems that the quarrel arose from a statement by Galileo in his *Il Saggiatore*‡ denouncing Scheiner for claiming priority for the discovery of the spots, which claim Galileo believed Scheiner had no grounds for making. The quarrel soon went beyond the mere question of priority of discovery, so that eventually not only the subject of the spots with their motions and nature, but practically the whole theory of the universe became involved in the discussion. Scheiner replied in his *Rosa Ursina* with a fierce attack on Galileo. No direct answer to this was made, but in the *Dialogues on the Two Chief Systems of the World* published two years later, the *Rosa Ursina* and the theories contained therein received some rather hard knocks. Many disgraceful personalities were exchanged by the principals and their adherents, which later proved very costly to Galileo. Scheiner became one of the foremost and most relentless of his enemies, and if not actually the leader in the crusade following the publication of the *Dialogues*, did all in his power to further the persecution of the Church, which later hounded Galileo to his grave.

* Kepler, *Opera Omnia*, **2**, 777.

† *Gal. Op.* **11**, 537.

‡ *Il Saggiatore nel quale con bilancia esquisita e giusta si ponderano le cose contenute nella Libra astronomica a filosofica di Lotario Sarsi Sigensano, ecc.* Roma, 1623.

The attempt will be made to throw some light upon the history of this quarrel, and to show upon whom the blame for it should fall. von Braunmühl and Carrara consider Galileo the guilty party, while Scheiner is held up to view as a much abused and innocent man. The Jesuits, naturally, have always rallied to the defense of the former member of their society, and have endeavored to show how unjust and unwarranted was the attack on Scheiner in the *Saggiatore*. von Braunmühl asserts that Scheiner made no attempts to claim priority, but only defended himself from the unwarranted attacks of Galileo. In this von Braunmühl is supported by Carrara. It is somewhat difficult to state with certainty just whether Scheiner did claim priority at this time or not. The statement in the letter of January 16th, concerning his fears has been quoted (page 217). Whether Scheiner at this time knew of Galileo's discovery of the spots may be open to doubt, but as will be shown later, it is very probable that Scheiner did know of the discovery, even before he wrote the first letter to Welser on November 12th. We recall Scheiner's anxiety to have the letter speedily published in order that the credit for discovery might not be "snatched from his hands." Other than this, there is no statement in Scheiner's writings at this time which can be construed as a direct claim for the discovery, but there is other evidence from which one can judge of his pretentions in the matter. This evidence will now be given, and the reader left to judge of its validity.

Mark Welser, the intimate friend of Scheiner writes to Johann Faber, Chancellor of the Accademia dei Lincei, March 16, 1612:*

> I do not know what Galileo thinks of the solar spots, because I never had a reply.....I do not believe that he can contradict the fact, but perhaps he will lament it, that, having been the first to observe these spots many weeks before, another claims the glory of it for himself; which moreover has nothing to do with the matter. And moreover I can affirm that my friend who calls himself Apelles knew nothing of the observations of Galileo, nor need it be considered a strange thing that in nature there be found various discoverers without one having the knowledge of the other. Moreover, if I am not deceived in my opinion of Apelles' modesty, I believe that he will readily yield this honor to anyone if proofs are adduced.

Ludovico da Cigoli writes to Galileo from Rome, October 19, 1612:†

> I was at the Marchesi's [Prince Cesi] who tells me that he was expecting letters from you, but despairs, and tomorrow which is Saturday he will again have them looked for at all the posts. But if there is no answer, resolve quickly, because all our friends judge it well that these letters [on the solar spots] should appear. Indeed it would have been better if you had done it when you were here, that is, spoken of the spots, so that this unknown Apelles might not have had a chance

* *Gal. Op.* **11**, 281.

† *Gal. Op.* **11**, 418.

to clothe (vestirsene) himself with it, as every one can see that he is trying to do.....And by many signs and ways of speaking, particularly at the end, it seems to me that he is a Jesuit [!], besides which Father Gambergier [Grienberger] defends and holds the opinion that they are stars.

Giuseppe Biancani, also a Jesuit, writes to Gio. Antonio Magini, May 17, 1613:*

As to the work of Galileo, I am glad that it has come to light. If he is not very careful in claiming this beautiful discovery of the solar spots he may be confuted by P. Christoforo Scheiner, because there are some of his [Scheiner's] manuscripts in the hands of many people, myself among others, which were spread abroad before he [Galileo] had printed those letters, and in which the first origin is seen.

In commenting on a statement in a book on optics by Father Aguillon published at Antwerp in 1613,† Prince Cesi writes to Galileo:‡

I certainly do not know to what extent this Apelles has become known and I wonder that the Fathers insist on giving him the priority in this observation, for they know how much earlier you showed and treated of it.

But of the modesty of Apelles, concerning which Welser writes so optimistically, there is no evidence. On the contrary, for we learn from a letter by Apelles himself to Antonio Magini that he evidently never had any intention of yielding the discovery. The letter is dated January 6, 1613; he writes:¶

Therefore I give you immortal thanks for such impartial judgment, with which you have so often defended with such great protection, my discoveries of the solar spots. I am unable to repay, except that I should show myself to you always mindful of your kindness, and that I should resort to you and that I should frequently confide myself and our Society to a name of such great authority.

Carrara asserts‖ that previous to the publication of the *Saggiatore* there had been no question nor quarrel over the priority of discovery, nor had Scheiner expressed explicitly any claim for precedence over others, either as to observations or writings. The arguments of Carrara which purport to uphold this are stated in a manner that is neither clear nor convincing. The assertion is also made that the statements in the writings of the friends and co-religioners of Scheiner were made without his sanction or knowledge, and hence he should not be held responsible for them. This may be quite correct, but there must have been some reasons to cause Scheiner's friends to write in the way that they did.

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* *Gal. Op.* **11**, 509.

† Francisci Aguilloni, e Societ Iesu, *Opticorum libri sex, philosophis ac mathematicis utiles.* Antverpiae, 1613.

‡ *Gal. Op.* **12**, 29.

¶ *Gal. Op.* **11**, 461.

‖ *Op. Cit.* 270.

If Welser, Cigoli, and others had cause to believe that Scheiner was making claims for priority, and from the quotations just given it evidently seems that they did, it is not unreasonable to suppose that Galileo also believed this for the same reasons, and the denunciation of Scheiner was not so very unwarranted after all. Just what these reasons were, outside of the statement in the letter of January 16th, and the remarks of his friends, is unknown; it may have been wholly due to the efforts of Scheiner's overzealous friends. At any rate it is certain that Scheiner did not see fit to reprove his friends for their remarks concerning him as the first observer of the spots.

It will be of interest to trace briefly the course of events which led up to Galileo's publication of his *Il Saggiatore*. While up to this time it may be that Scheiner made no direct claims for priority of discovery, his friends had certainly done so for him. Not only had the question of the discovery and nature of the spots been brought up, but every one of Galileo's other discoveries had been attacked or impugned in some manner or other. The new star of 1604, the satellites of Jupiter, the mountains of the moon, the mechanics of floating bodies, the phases of Venus with the deduction therefrom supporting the Copernican theory, all these and others, each in turn, had been attacked with extraordinary venom and malice. In particular, the doctrine of the motion of the earth in accordance with the Copernican theory, which was upheld in the letters on the Solar Spots was especially obnoxions. The uncompromising boldness with which Galileo published and supported his opinions raised against him a host of enemies. The Aristotelian professors, the Jesuits, and the timid but respectable persons who at all times dread innovations, whether in religion or in science, all began to draw together for the common defense against this philosophical tyrant who threatened them with the dangers of too much knowledge. No longer able to combat Galileo's hard facts and powerful arguments with metaphysics and the assertions that the facts were "faults" in his devilishly designed instruments, and that his arguments were vain glorious and "scientifically" absurd, his opponents went back to the fifth Century arguments, and taking their stand on theology, raised the cry that the Church was in danger. On the ground that these astronomical teachings were incompatible with Scripture, a great din was raised; and the controversy as to the relative validity in scientific matters, of observation and reasoning on the one hand, and the authority of the Church with the interpretations of Scripture on the other, was thus commenced. A controversy which, although the battle-field has shifted from one science to another, has continued almost to the present day; and which eventually proved to be the undoing of Galileo.

In 1615 Galileo went to Rome in order better to combat the intrigues against him, which had now grown to formidable proportions, but obtained small satisfaction. Early in the next year he was summoned before Cardinal Bellarmine, and on the authority of the Holy Office (The Inquisition) admonished no longer to teach nor defend the "false and philosophically absurd, and formally heretical" doctrine that the sun and not the earth was the center of the world;* which doctrine had been upheld in the *Istoria* and other publications.

In the year 1618, three comets appeared, Galileo, as was customary, published his views concerning these objects through the medium of Guiducci, a Florentine disciple.† In this essay the opinions of the Jesuit Orazio Grassi were so indiscreetly attacked as to further arouse the ire of the whole Jesuit College at Rome. Grassi in reply published a pamphlet under the name of Lotario Sarsi,‡ which in turn was an onslaught on Galileo's theory of comets, and was full of abuse of Galileo and his school.

By this time, as may be easily surmised, Galileo had pretty well succeeded in attracting to himself the enmity and hatred of a large number of the Churchmen, and others in Italy and elsewhere. Their attacks, open, and veiled, as they more frequently were, were naturally a severe trial and most annoying to Galileo. To these must be added the admonition of Bellarmine, and the claims of Scheiner and his friends for the discovery and correct theory of the solar spots.

Whatever attempts were made by Scheiner and his friends to secure the discovery of the spots were little to the liking of Galilo; nor was he better pleased with the attack of Grassi in his pamphlet on the comets. As a general remonstrance and defense against all these persecutions and attacks, Galileo wrote and published his *Il Saggiatore*. This piece of brilliant sarcastic writing was directed primarily against Grassi and his supporters. It is a masterpiece of ingenuity and skill, for the author not only dexterously avoids the snares laid for him, but brings defeat and ridicule upon his opponents at every turn. The *Saggiatore* was dedicated to Pope Urban VIII, formerly Cardinal Barberini, who later figured so prominently in the trial of Galileo.

In the *Saggiatore* Galileo laments that in general his discoveries have been impunged and the reasonings thereon made a contention from all sides. In particular he mentions the letters on the Solar Spots, for the defense of the Copernican System mentioned in these had resulted in the admonition of 1616, and writes:¶

* Fahie, *Galileo,—his Life and Work*. p. 163.
† *Discorso della Comete di Mario Guiducci*. Firenze, 1619. *Gal. Op.* **6**, 39.
‡ *Libra Astronomica ac Philosophica*. Perusiae, 1619. *Gal. Op.* **6**, 111.
¶ *Gal. Op.* **6**, 214.

The letters on the solar spots, by how many people and in how many ways were they opposed. And this material, which offers such a field for the development of our intellect in wonderful speculations [the motion of the earth around the sun], was either not believed by many, or was regarded as not worthy of consideration, yes, even despised and laughed at. But by others who did not wish to agree with my views, there have been brought up against me ridiculous and impossible opinions, and one in particular who was subdued and convinced by my arguments has tried to despoil me of that glory, but it belongs to me, and pretending not to have seen my writings he attempted afterwards to claim for himself the original discovery of such great wonders.

This was the attack on Scheiner which has been considered so unwarranted and unreasonable. It was perhaps uncalled for, and unnecessarily severe, particularly in the accusation of plagiarism. But recalling what has preceded, the claims of Scheiner's friends, the attacks of the Jesuits, and the other persecutions which Galileo had continually to contend against, it certainly does not seem sufficiently severe to have merited the hatred and animosity which Scheiner displayed toward Galileo during the remainder of his life.

On Scheiner's arrival in Italy in 1624, inquiring what novelties there were in mathematical works, he was presented with a copy of the *Saggiatore*. Concerning the impression made by the passage quoted above, he writes in the *Rosa Ursina*:*

I frankly acknowledge that I at first thought that someone else and not Apelles had been attacked by the Italian Accuser [Galileo]. Nor did I know that that author had ever been injured by Apelles in any writing, or word, or deed, or sign, as he insists with such unreasonable incrimination. But I know the falsehoods spread about by some in regard to the solar spots; moreover I had seen long before, and had read the Mundus Jovialis of Simon Mayr, so I thought that these invectives were hurled by this Symbolist against him. But after I saw Mayr named and punished as would be expected, not on account of these [the spots] but on account of other crimes against the author [the supposed plagiarism of Jupiter's satellites], I have seen a quarrel started against the very contents of the Apelles letters. This one finding particular fault because he [Apelles] had taken for himself the glory of the first discovery of the solar spots, a glory which the Accuser asserts belongs to himself. Since these, and other remarks will not fit others, and since besides Apelles no other discoverer of the solar spots appears,† who will furnish a target for the Accuser, the glory of which he proclaims to be his by profession or possession, hence scarcely any doubt remains but that the last sentences in the complaint, which I shall only mention, are directed against Apelles.

And thus the quarrel commenced. Scheiner based his claims for priority on the published observations. He doubts Galileo's statements concerning the observations at Padua, for the first actual observations

* Lib. I, p. 2.

† This assertion convinces Carrara that Scheiner was ignorant of both the discovery and writing of Fabricius. But it is to be remembered that the *Mundus Jovialis* which Scheiner has just stated to have read contains the statement. "The first discoverers and observers of the solar spots are the two Fabricii, father and son." Evidently Scheiner had a bad memory.

given by Galileo are dated April 5, 1612, while Scheiner's first authentic observations are dated October 21, 1611. Scheiner also objects to Galileo's priority because there was no announcement of the discovery, whereas all Galileo's previous discoveries had been announced in an anagram, etc. But all this has already been discussed in detail.

(*To be continued.*)

THE SPIRAL NEBULAE.

JOHN MILLIS.

No one of those developments of recent astronomical research that have been effected by the application of advanced photographic appliances and processes to the study of the heavens is more wonderful and mysterious than the great number of nebulae that have been disclosed and the revelations regarding the forms and structure of these strange bodies that the photographic plates present. This applies especially to the discovery made in recent years that a very large majority of these remote and ghostly aggregations of matter in space exhibit certain general features of form that are common to all. The greater portion undoubtedly approximate to a more or less well-defined flattened circular or disc-like shape in general outline and their internal structure is such as to give an appearance of a flat spiral, the twist being about an axis perpendicular to the nebular disc. Many nebulae that do not decidedly show the spiral characteristics nevertheless exhibit certain quite well defined approximations or tendencies to such a structure, while the general disc-like form is so common as to make the departures from it seem exceptional. Starting from the few observed examples of nebulae that could be made out with the earlier telescopes by direct vision, the number has increased with improvements in the methods and instruments for observation until at present it is estimated that the total number within range of available means of detection must now be reckoned in the millions, or at least as over one million. The inference with respect to the prevalence of the nebulae throughout the entire material universe is obvious, and we cannot escape from a profound sense of conviction that there must be something deeply and fundamentally significant in these forms.

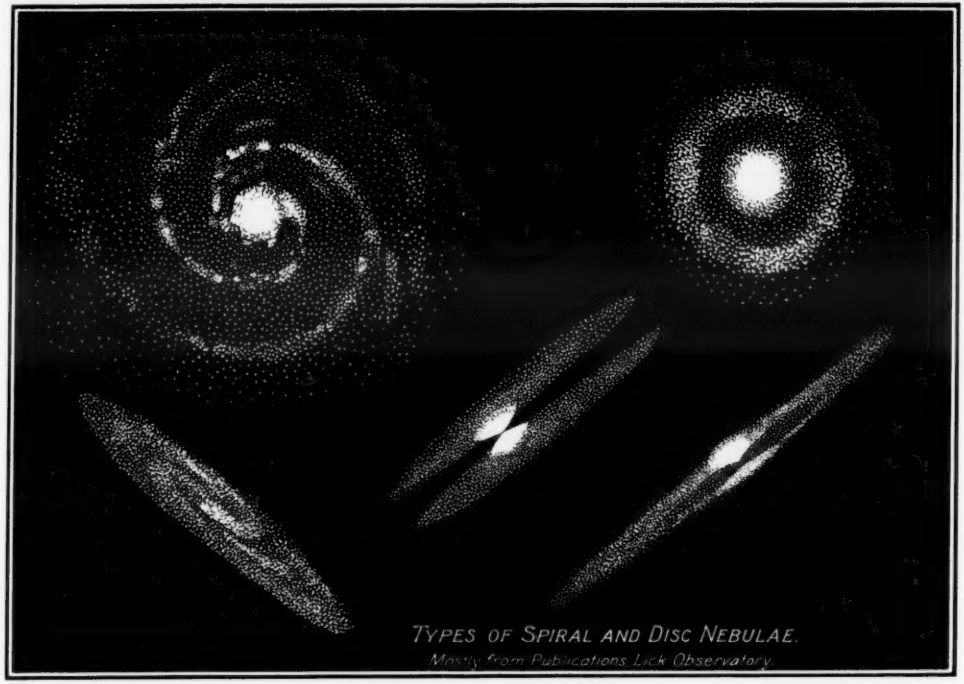
Naturally there has been much speculation on this subject. The theories that have been enunciated heretofore to account for these spiral and disc-shaped nebular forms differ in various details, but those

that seem to have been regarded as having the largest measure of plausibility attribute the cause to the close approach, to the grazing, or to the eccentric or tangential contact of two bodies in space, with a resulting disassociation of the matter and the formation of a nebular whirl in a plane that contains the paths which the two bodies concerned were pursuing before the collision, or before the action which resulted in the formation of a nebula took place. There are grounds for regarding this idea as radically inadequate and untenable. Whatever plausibility it may have for certain special and well defined forms of the spirals, great difficulties are found in trying to make it fit the generality of the shapes that the photographic plates show, including the apparently abnormal or irregular and erratic forms. A theory to be admissible must account for the freaks as well as the "regular" spirals. Possibly the correct explanation is one of surprising simplicity.

When a lead bullet fired from a rifle strikes a flat iron target squarely, it "spatters" laterally in various directions, mostly at right angles to the direction of the bullet's flight, or parallel to the face of the target. A small residual fragment is usually found which is of a disc-like or round button shape with ragged edges. This is the central part of the bullet which remains after the greater part of it is spattered away upon impact with the target. If two bullets of equal size and moving with equal velocities should meet squarely head-on when fired from opposite directions a similar result for each bullet would follow. Each would be in effect a fixed target for the other and all or the greater part of both bullets would be dissipated and scattered through a circular or disc-like space whose plane would be at right angles to the line which defined the paths of both bullets. With sufficiently great velocities the substance of the bullets would be "blown" into minute globules of melted metal, would be disintegrated into a mist of lead, or would even be partly or wholly vaporized. It is not practicable to conceive any conditions of collision that would result in a distribution of the resulting fragments or vapor throughout a disc-like space whose plane would be *parallel* to or would contain the paths which the colliding bodies were following before impact. So far no account is taken of any motion of rotation of either bullet about an axis within itself.

Now imagine two spherical astronomical bodies of equal size and mass colliding "in space." We need not stop to consider actual dimensions or distances or velocities, so long as the respective components of velocity are equal and the relative velocity of approach is sufficient to cause the disintegration and dissipation of the matter involved. Assume a direct head-on collision. The result would be similar to that above described and the locus of the dissipated matter would be circular and

PLATE XVI.



TYPES OF SPIRAL AND DISC NEBULAE.
DRAWN BY JOHN MILLIS.

of a flattened disc-form;—mathematically speaking a "volume of revolution" having its axis coincident with the paths of the colliding bodies, but *not* in fact generated by any revolution of matter. The process of dissolution of the colliding bodies and of the projection of the resulting debris laterally will be progressive and of varying intensity, however sudden the action. It will be most intense at the moment of first contact when the total masses and the highest velocities of both bodies are involved. The radial distribution will, however, be uniform in all lateral directions if we assume uniformity in the composition of the colliding bodies throughout their respective masses, a square head-on collision, and no motion except that of mutual approach. This will produce nebulae of the "ring" and possibly some of those of the "planetary" types.

Now suppose that motions of revolution are involved, in one or in both of the colliding bodies, in addition to the relative motion of translation. Suppose both bodies, or one of them alone, to be revolving about some axis passing through the center of the revolving body. It is easily conceivable that this would cause a variable distribution of the fragments or debris of collision along different radii of the disc-shaped locus after the bodies had collided and while they were "grinding" up and smashing themselves and each other. The revolving body would retain a residual of revolution about some axis within itself during the process, there would be one or more radii of maximum ejectment of the debris, which would revolve about the common line along which the two were travelling at the moment of impact and in a plane at right angles to it. The distance to which the debris or litter resulting from a collision is projected will be variable as determined by the intensity of the action at any particular stage in the disintegration process and by the opposing gravity effects of the remaining masses of the two bodies at that stage. Viewing these conditions in their entirety it is not difficult to see in them a situation which might reasonably produce a more or less perfect spiral nebula, generated progressively from the extreme outer limits inward;—not necessarily a revolving mass but a *form* which may be fixed in space as a whole and which is outlined by the position of the products of the general smash-up after they have practically come to rest. The form is not in process of being wound up on a turning center, nor is it being unwound from a similar center, though its parts may have some residuals of a motion of revolution. No mere close approach and no tangential or eccentric collision or "side swipe" could produce similar results in the generality of cases.

While the foregoing contemplates in general two solid spherical bodies of uniform composition, the same general principles would apply

to bodies of compound internal structure or to aggregations of matter in whatever form or state of composition. To account for the great variations in the spiral forms, as well as for the forms that are not distinctly spiral at all, we are at liberty to make almost unlimited assumptions regarding the relative masses of the colliding bodies, their relative translatory velocities, and especially as to their motions of axial revolution, including the relative directions and speeds of such revolutions and the relative positions of the axes at the time of collision.

The actual forms shown in the photographic plates present the widest field for speculation with the foregoing general assumptions in mind. There are spirals of all degrees of perfection, from the beautifully formed ones with the two arms which a prominent theory heretofore promulgated calls for easily recognizable, through many variations to crude and irregular shapes that require some imagination to be classed as spirals at all. There are nebulae which indicate that the colliding bodies may have been entirely dissipated and "blown" a long distance from the center. There are others in which a central nucleus of matter appears, suggesting portions of the original bodies that escaped entire dissipation. There are shapes that suggest two spirals superposed—one right handed, the other reversed—as though each of the colliding bodies had developed a spiral form of its own. Several of the nebulae that appear to be of the spiral or at least of the disc-like form, which are seen edgewise, show a dark central space or band that may be attributed to something like a "rebound," when the masses that formed the nebula came together.

Speculations on the "age" of the nebulae are even possible on the assumption that condensation or collection sets in after the collision and explosion. The photographs show nebulae approximating to uniformity in detail structure; others with knots and patches more or less conspicuous and well defined, suggesting that the process of condensation has begun, and others that indicate formation of some individual stars. Still more remarkable we have photographs of what are plainly concentrated groups of individual stars which show clearly a general spiral arrangement for these individuals. There are, moreover, photographs of some conspicuous nebulae that without too great a stretch of the imagination can be conceived as having been produced by the simultaneous collision of *three* or more bodies with a mutual "rebound" on quite an extraordinary scale. Lastly may be mentioned the wonderful "net-work" nebula in which can be detected a twist of another kind, like a long screw of "quick pitch." Could this have been formed by the collision of two bodies, one of which dominated in the translatory motion, with the result that both were not brought up "all standing" but that the two were carried along through space while

grinding together and throwing out the debris along one or more predominant directions? If these radii of projection revolved about the path of translation, in a plane normal to it, they might have formed the screw-like shape which we see, like a pin-wheel that escapes from the nail which constitutes its restraining axis and runs wild!

This theory also suggests a possible explanation of the deeply mysterious "double star drift" that has been observed. If the star group or "universe" in which the earth is located is a spiral nebula—and the Milky Way is a plausible indication that it is—it is conceivable that this has resulted from the collision of two aggregations of matter which were both dissipated and the resulting nebular matter has now assumed the form of individual masses or collections which constitute the stellar universe now visible to us. These individual masses, now seemingly intermingled, must have belonged originally to the one or the other of the two colliding masses, and it is therefore possible that they have individual residual motions which distinguish each as belonging to one or the other of two originally separate groups, while in their present distribution throughout the sky as seen from our earth no such classification is suggested. There is even something in the positions of the outside spiral nebulae with respect to our supposed Milky Way spiral "Universe" and with respect to each other that suggests some kind of law and order in the arrangement of individual "universes."

On the scale of things we are here considering, as compared to ordinary human conceptions, a collision and "explosion" with the dissipation of the matter concerned into the nebular form may of itself involve a period of duration which we would designate as protracted, to say nothing of the time that is occupied in the condensation and collection of the scattered and vaporized matter again into planets and suns and further into a state of aggregation or concentration which may be a condition precedent to another collision with a similar mass and a repetition of the whole process; thus constituting the grand cycle of transformations which all material substance undergoes everlastingly. Not only does the process continue without any end, but *it never had any beginning*! The bearing of these ideas on quite a comprehensive generalization and simplification of our theories of cosmogony will be apparent. To put it in terms that may sound somewhat ponderous, no cosmological theory which purports to be all-inclusive can be tenable if it predicates either a primordial incipiency or an ultimate finality.

All this calls for a measure of audacity on the part of one who engages in such speculations. It is customary to stand aghast at things which are big and distances which are long and periods of time which are immense, but it is reassuring to him who ventures into these regions of thought to reflect that among real things nothing absolute

in the way of dimensions is recognized by nature. It is necessary simply to adapt oneself to the "environment." It is legitimate to consider the relations and characteristics of worlds, planets, suns, and nebulae, as though they were of the dimensions of birdshot, marbles, golf balls, and toy balloons, affected by actions on a commensurate scale and which continue over periods of time of corresponding magnitudes. Exactly the same principle is applicable the other way about when we speculate on the properties and relations of molecules atoms and ions.

These reflections do, however, suggest that we need new terms in, ordinary language,—something to express conceptions like superlatively unlimited space, multiple universes, super-infinities, and transcendental eternities.

Providence, R. I.
April 15, 1916.

THE POLAR REFLECTING TELESCOPE.

An Amateur's Attempt at an Observatory that may be made comfortable in cold weather.

RUSSELL W. PORTER.

There have been several attempts at various times in the past to so arrange the optical parts of the telescope, as to provide a closed observing room maintained at a different temperature from that of the outside air, the object being to mitigate the rigors of astronomical work during the winter months. Among the many efforts to demonstrate this principle may be mentioned the Equatorial Coude at Paris, the Hartness Turret telescope at Springfield, Vermont, The Gerrish Polar instrument at Harvard, and the Sheepshanks telescope at Cambridge, England. These are all refractors.

The difficulties of the problem are great; the severe and long drawn out periods of observing in extreme low temperatures would long ago have been done away with, had the proper means been found for overcoming them. The writer retains a vivid recollection of the many hours at the eyepiece of a transit instrument, on a north polar expedition, and the damaging effects that such body exposures have on the quality of the work secured.

Were the efforts to bring about a closed and warmed observing room to need the sanction of professional astronomers they would be met in these words of Professor Turner*.

"It is specially important to those who regard astronomy as an amusement rather than as a profession that they should not be gradually weaned from it by discomforts, as is so often the case.....With some device for bringing the eye end of the telescope into the comfortable study, the fascination of the work would be much more lasting..... The matter is worth the attention of amateurs." He cites the opinion of Professor Pickering who wonders why amateurs have not exerted themselves further in this direction; and the case of Director Lowey at Paris, who, with advancing years, had given over the observational work of the observatory to younger men, but that, on the completion of the Equatorial Coude, he returned to the work with renewed interest.

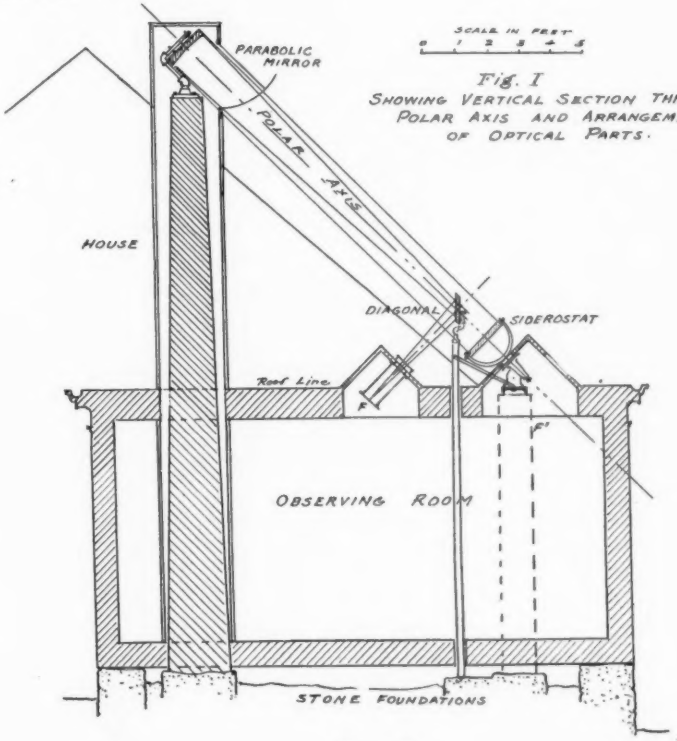


FIGURE I.

* Modern Astronomy, (1901), p. 130-131.

It was more for the pleasure of working out the mechanical details of the problem than with any hopes of successfully solving it, that led the writer to the results which the present article is intended to describe.

As will be seen from Figure I, the arrangement involves the use of the Newtonian reflecting telescope, inverted, and rigidly fixed in the polar axis; and a siderostat in the same axis. All the optical parts (excepting the eyepiece) are outside and above the observing room, supported on piers that carry down to the ground without contact with the building.

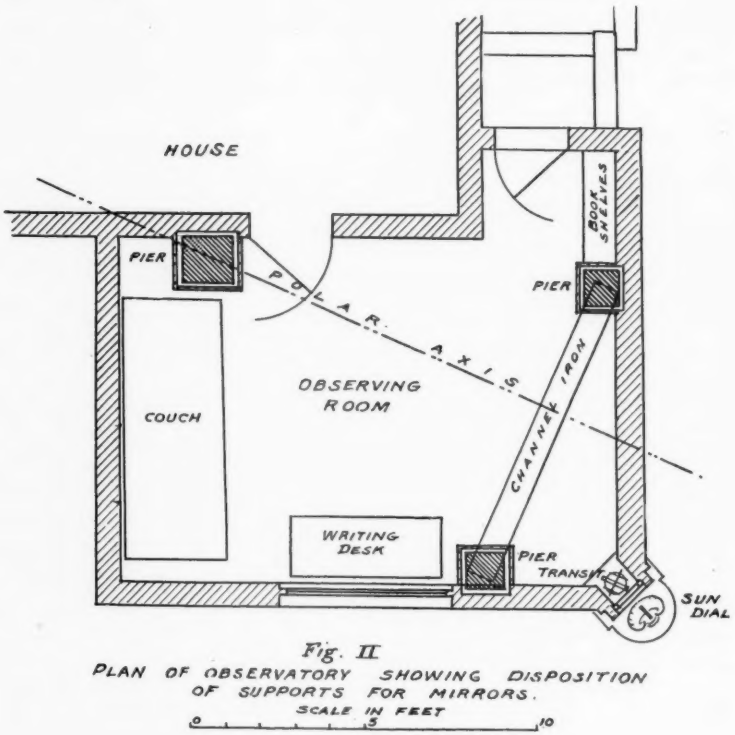


FIGURE II.

With this arrangement, all light from the siderostat reaching the parabolic mirror passes along the polar axis: it is thence returned to the diagonal mirror along the same axis, where it is again deflected through the roof to an eyepiece at the focus in the room below.

As originally designed and built, the Herschellian form was tried, and the parabolic mirror was tilted enough to return the light rays direct to a focus just below the siderostat at F′ (Figure I), thus saving the extra reflection of the diagonal.*

Sufficient astigmatism, however, developed in the image at the focus to make this form undesirable, so an alteration to the Newtonian form was made. When this change was effected, knife edge tests of the image of a star at the focus were in every way as satisfactory as the laboratory tests when the mirrors were being figured.

The observatory was built adjoining the southwest corner of the writer's home. A part of the heavens to the northeast is obscured by the house, and the immediate vicinity of the north pole is cut off by the housing of the curved mirror; but as this is the least interesting part of the heavens the loss has not been greatly felt.

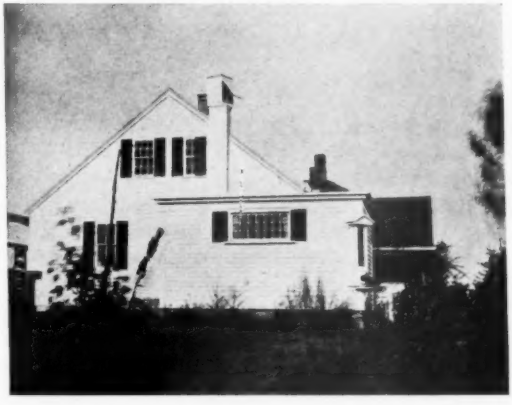


FIGURE 1.
The house and observatory from the southwest.

The siderostat is driven by a clock actuated by a weight. It is so fitted with setting circles, that an observer at the eyepiece can bring any desired part of the available heavens into his field of view. A photograph taken from below and looking up into the monitor surrounding the siderostat, shows the setting circles in right ascension and declination, and their control from the eyepiece.

* This accounts for the siderostat being supported by the two piers carrying the channel iron, giving the necessary open space immediately below the siderostat support. With the Newtonian form this arrangement is, of course, unnecessary.

It is now in order to cast up the advantages which this very unusual form of telescope possesses, and then to enumerate its faults. It will be well to state here that some of the defects which have developed are due to imperfect mechanical details, made necessary by the writer's inability to afford costly machine work.*

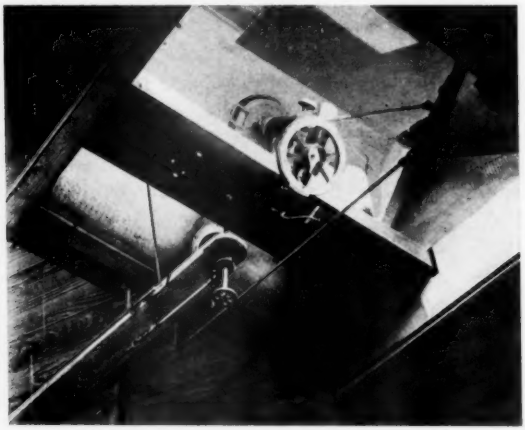


FIGURE 2.
Looking up at the ceiling of the observing room, showing the siderostat mounting, and controls from the eyepiece just outside the lower left hand corner of the photograph.

ADVANTAGES.

Unquestionably the greatest gain lies in the amateur being able to work in a closed, comfortable room, which is as much a part of the home as his den or living room. It is lighted and heated like the rest of the house. With all his books and data at his elbow he will freely consult his references whenever a question arises at the eyepiece. A couch in the corner will allow him to "make a night of it" if he chooses, without disturbing the household. The host may present to his guest the wonders of our universe with the same ease as showing him a beautiful painting in the library.

* The cost of materials was roughly as follows:—

For the optical parts—Glass discs	$ 40.
Abrading material	5.
Silvering	5.
For the building itself	100.
Total	150.

As all work was done by the writer at odd times, no figures for labor are available.

The other advantage lies in the convenience of a fixed eyepiece. The observer, once he has comfortably adjusted himself in the observing chair, need not alter his position. All controls are at his hand—the quick setting on any object, starting, stopping and regulating clock. The writer has found this stationary position of especial help in drawing the details of the Moon.

FIGURE 3.
The writer's first observatory, built by himself, to house a 6-inch equatorially mounted refractor. The dome is painted canvas on a light wood frame, and weighs but two hundred pounds.

DISADVANTAGES.

There will always with this form of telescope be a part of the northern heavens, lying behind the box covering the parabolic mirror, that will never be seen. The area is, however, small and contains none of the bodies of the solar system.

The siderostat mounting was found to be not sufficiently heavy to prevent the image vibrating when there is a strong wind. In fact, when photographing, the air must be quite calm in order to obtain negatives of good definition. The siderostat was improvised from a six-inch Mogey equatorial mounting, by removing the declination axis which carried the telescope tube, and bolting to the polar axle a yoke in which the flat swings. As a consequence the mirror, weighing some forty pounds, considerably overhangs the support of the mounting—a construction mechanically weak. A proper mounting would probably overcome this trouble, as no further noticeable tremors could be detected originating in either the parabolic mirror or diagonal.

The siderostat mirror adds one more reflecting surface to the two already found in the common reflector, a certain amount of light thereby being absorbed and lost.

Condensation on the three mirrors have on certain nights proved very troublesome, and it is difficult to see how, in this form of instrument, it could be overcome. Hot, dry cloths, held close to the silvered surfaces will remove the moisture, but only for a time.

No dimensions have yet been given. The curved mirror is 16 inches (41 cm) in diameter and has a focal length of 15½ (4.7m) feet. The siderostat is also 16 inches in diameter. Both of these mirrors are 2 inches (5 cm) thick. The diagonal mirror is an ellipse whose diameters are 10 (25 cm) and 7 (18 cm) inches. It is one inch (2.5 cm) thick. All the mirrors were ground and figured by the writer at his home on the Maine coast.*

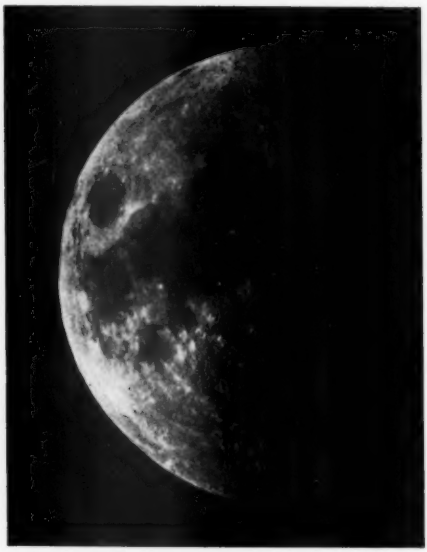


FIGURE 4.

It will thus be seen that the polar reflecting telescope, as worked out by the writer, while proving the feasibility of the warmed ob-

* For the benefit of those who desire to make their own reflectors, they are referred to M. Thos. Fullan, Director of Instrumental Section, Society of Practical Astronomy, Auburn, Ala., who, I am sure, will be glad to furnish simple directions for prosecuting this fascinating work.

serving room, is still subject to the evils of condensation and wind tremors: that the latter with proper mounting can probably be removed, but the former probably cannot. On the whole, its maker was very well pleased with the results. He has had but little time as yet to give it a fair trial, and has been something over a year in making it.

The photograph of the moon accompanying this description was a first attempt to replace the eyepiece with the dry plate, and is probably not a fair sample of what the instrument can do. It was taken in this way.

The driving clock was disconnected from the siderostat and attached to the ceiling in the vicinity of the focus: the end of a cord wound around the clock drum shaft was then attached to the end of the plate-holder which rested in ways parallel to the apparent motion of the moon's image. The clock was then started and the plate exposed (2½ seconds). If it were desired to take long exposures, it would be necessary to rotate the plate-holder.

In closing this account the writer feels quite ready to recommend this instrument, not to professionals, but to those persons who, appreciating the wonders of the heavens, have hitherto foregone the pleasures of astronomical work from a disinclination to submit themselves to its inconveniences. The writer's experience has been this: four years ago he acquired a six-inch refractor and mounted it beneath the dome of the standard type. As a consequence, months at a stretch would pass, especially during the colder weather, without the observatory being used. It being only a hobby, he simply would not go to the trouble of bundling up, and the discomfort of standing still and shivering through the cold nights. He thus missed some of the best nights of the year for seeing. When the new observatory was completed, the exact reverse obtained. Scarcely a clear night passed that he was not at work in the room.

There is another form of reflecting telescope which it would be interesting to apply to this idea of a closed observing room—that is the Cassigranian. The arrangement is suggested in Figure III. As will be seen, all three mirrors are enclosed in the telescope tube which revolves in the polar axis. The eyepiece is just behind the parabolic mirror, in the room, at a convenient height above the floor. The flat mirror is at the opposite end of the tube in bearings at right angles to the polar axis, and a part of the tube removed to permit the maximum range in declination. The driving mechanism would be applied to the upper end of the tube, at which both controls—right ascension and declination—would be located.

Advantages of this arrangement would be—the bringing of all supports much nearer to the ground; the assembling of all optical parts in a compact unit; the convenient position of the observer when sitting at the eyepiece; and the probable reduction of troubles arising from wind tremors and condensation. Against these points in its favor must be mentioned the limited range in declination—from the southern horizon to about thirty degrees north of the zenith.

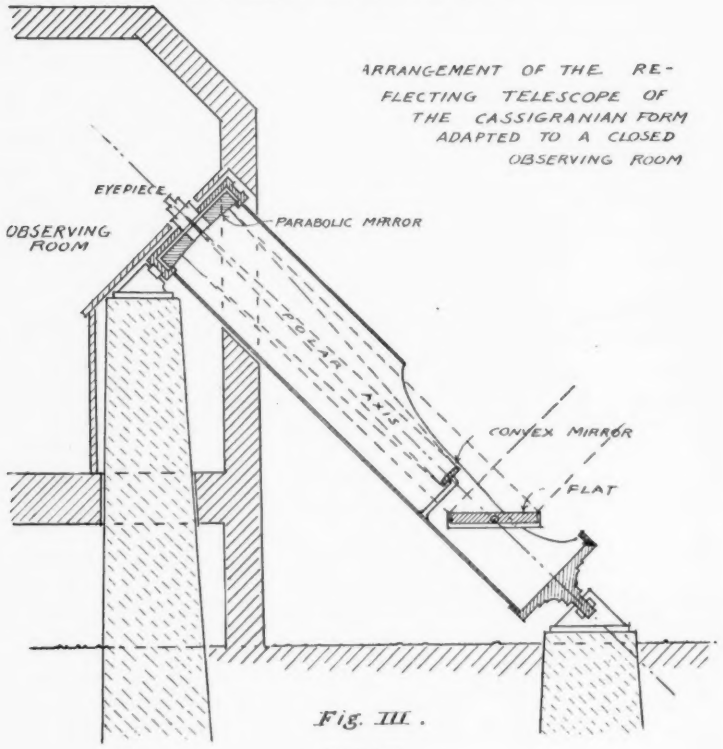


FIGURE III.

One or two other features of the observatory may be of interest. In Figure II may be seen a small corner bay window. Here is located a four inch alt-azimuth instrument. A south meridian mark, situated some two miles out in the Atlantic Ocean on the Old Scilly Ledge, serves to bring the instrument into the meridian for the purpose of obtaining correct time. Just outside of the transit window is seen the Hartness sun dial, from which, after adjustment, the mean time may be read off

directly. Inside the observatory the walls are covered with maps and charts of the north polar regions where the writer has spent many years in astronomical and topographical work—Franz Josef Land, Greenland, Labrador, and Alaska.

FIGURE 5.
The transit window where the sun is observed for time, with the Hartness Sun Dial below.

The observatory is located on a point of land jutting out into the Atlantic at the small fishing town of Port Clyde, lying about one hundred and fifty miles northeast from Boston on the Maine coast.

"Land's End" Port Clyde, Maine.
December, 1915.

THE RUINED LUNAR CRATER WALLS.

JOHN A. COOK.

For more than thirty years I have been studying and observing the Lunar surface in an amateurish way, using instruments ranging in size from two to ten inches, and have arrived at conclusions at variance with those, so far as I know, held by the great selenographers living and dead regarding the above mentioned features.

We find them scattered about over the floors and shores of the Ocean and seas. When found fully down on the sea floor they often present but the merest trace of a ring. Those on the shore will show that part down in the sea destroyed, while that portion of the crater on higher ground is intact.

Writers speak of them as Ruined walls, Submerged walls, Melted walls, and often as destroyed by some unknown cause.

I have searched the works of Neison, Pickering, Elgar, Lohrmann, Fauth, Nasmyth & Carpenter, Serviss and a host of other more general works to find if some one would not suggest water erosion, and if not why not, to account for their ruined condition, but have failed. The opinion seems to prevail that they have been submerged, inundated by molten matter welling up from the interior burying them. As this would require material enough to spread over between two and three millions of square miles, and to a depth of more than a mile, and as we find no trace of such a lava outflow except in the seas, if there, I find it difficult to accept the theory, even with my great respect for the above named masters of selenography.

Some of the above named writers claim they find no trace of water ever having been on the moon, but most writers with whom I am familiar seem willing to admit that there may have been water in those old basins once.

The moon is covered with mountains, and as water enters extensively into mountain making on our planet, we may reasonably assume that it did so on our satellite, and how the moon could have left the earth, either as nebulous matter, or as a chunk out of the Pacific basin, which theory I do not think will hold water, it is impossible to understand why the elements of which water is composed did not accompany it.

Aside from theory, I think we see the evidences of the effect of water everywhere. Fill those basins with water and the tides produced by the earth would be vastly greater than any we have here on earth. Laden those waves with sand, gravel and rock, and any crater wall or other elevation that opposed them would soon be ground away, and its debris scattered about forming those long, low, winding sand ridges, seen in such numbers over the sea floor under a low sun.

Many writers speak of such formations as Fracastorius and Letronne as bays, yet in nearly every instance it is possible to trace the complete wall under oblique light. Sinus Iridium may have been a huge walled plain, or it may have been a true bay, but from the number of sand ridges in the neighborhood, it makes it easy to imagine that a wall has been disintegrated by the grit ladened waves crossing the sea of showers.

The base of the Apennines on the Imbrium side shows the effect of tidal action, and the eroded material has been deposited in the near by part of the sea, forming the shallows, shown on the maps as Palus Putredinis.

Any one studying the broad, flat floored, perpendicular walled canyons connecting Crisium and Tranquility, under proper illumination and with a power of 600 or 700, will, I think, be convinced that he sees the effect of torrential currents surging through them.

It is needless to continue this line of thought. The evidences of wave effect I think are preponderating and can be seen if looked for without prejudice. And when we admit that those basins were once filled with water, and consider the immense tides that would be produced by the earth's attraction, and that we find these ruined walls always just where the tides would have reached them, and never anywhere else, why not ascribe their ruination to water erosion?

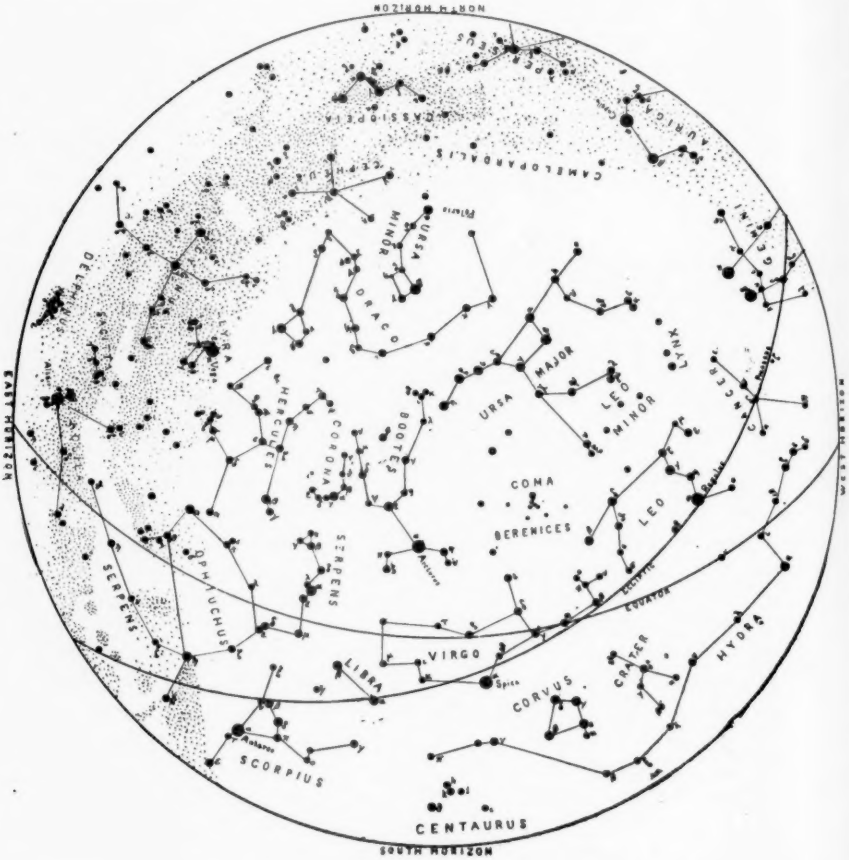
There have been countless maps and drawings made of the Lunar features, but never with the power that might now be applied. And to say that 200 or 300 will show all there is to see is a mistake. What we need is some one with the mental and instrumental equipment of Professor Percival Lowell to devote the necessary time to this work, and then give us a map and a book that will make him rich in gold and the world richer in knowledge of our satellite.

Macon, Mo.
Jan. 28, 1916.

PLANET NOTES FOR JUNE, 1916.

CLIFFORD C. CRUMP.

The sun will move eastward during the month from the constellation Taurus into Gemini. On the twenty-fifth of the month it will be in the region of μ Geminorum and at the close of the month it will be just a few degrees south and about an hour preceding Pollux. On Wednesday, June 21, the sun will reach its greatest northern declination, $+23^\circ\ 27'$. This date is called the summer solstice.



THE CONSTELLATIONS AT 9:00 P. M. JUNE 1.

The phases of the moon for this month are as follows:

First Quarter	June	8	at 6 P.M.	C.S.T.
Full Moon		15	" 4 P.M.	"
Last Quarter		22	" 7 A.M.	"
New Moon		30	" 5 A.M.	"

The moon will be at apogee twice during the month, once on June 3, and again on June 30. It will be at perigee on June 16.

Mercury will continue its retrograde motion until June 17, it will then move eastward. It will be in a favorable position for observation on the morning of June 29, just before sunrise. It will be found in the constellation of Taurus.

Venus will continue its easterly course in the constellation of Gemini until June 12. On this date it will begin to move with a retrograde motion. At the beginning of the month it may be seen low in the western sky just after sunset. During the month it will become invisible.

Mars will move westward in the constellation Leo. It will continue to be in a favorable position for observation.

Jupiter will be seen in the morning sky in the constellation of Pisces.

Saturn will be visible in the early part of the month only.

Uranus will be found in the constellation Capricornus. It will be in position for observation.

Neptune will be approaching the sun in the constellation of Cancer. It may be seen in the western sky in the early evening.

Mars at the Opposition 1915-16.—A curious set of features, secondary to the main canal network, have become apparent on Mars. Within some of the polygons made by the intersections of the larger canals a tiny dot has been descried at this observatory, joined to a corner and to the sides of the polygon by lines so slender they usually appear as a string of minute beads. The effect is of a centrally woven web, spun within the borders of the polygon, of a more minute order of tenuity than the polygon itself. Elysium was the first example of this phenomenon with the Fons Immortalis and five connecting spokes. A second has ust been detected in eastern Arcadia, the region bounded by the Acheron, Lapadon, Clarius and Psillis; the Fons Senectutis and four spokes reproducing the same singular arrangement. These details are so minute and so curiously disposed as to suggest a new order of Martian markings.

PERCIVAL LOWELL.

Flagstaff, Arizona.
March 30, 1916

Occultations Visible at Washington.

Date 1916	Star's Name	Magnitude	IMMERSION. Washington M.T.	Angle f'm N.	EMERSION. Washington M.T.	Angle f'm N.	Duration
			h m	°	h m	°	h m
June 8	*p*5 Leonis	5.3	7 14	148	8 30	288	1 16
11	87 Virginis	5.8	12 18	187	12 34	213	0 16
13	*b* Scorpii	4.7	13 48	129	14 42	238	0 54
16	172 B Sagittarii	5.8	8 31	53	9 23	299	0 52
16	189 B Sagittarii	6.1	11 13	44	12 15	294	1 2
16	208 B Sagittarii	6.1	15 8	47	16 14	269	1 6
18	29 Capricorni	5.5	13 56	50	15 12	249	1 16
21	22 Piscium	5.8	14 50	132	15 5	155	0 15
22	136 B Piscium	6.5	15 47	18	16 47	270	1 0

VARIABLE STARS.

Minima of Variable Stars of Short Period.

[Calculated by Agnes E. Wells at Goodsell Observatory.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5h; Central Standard 6h; etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1916 June
	h m	° ′		d h	d h d h d h d h d h
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.8	27 21
RT Sculptor.	31.5	−26 13	9.6—10.5	0 12.3	3 15; 11 7; 18 23; 26 15
UU Androm.	38.5	+30 24	10.7—11.9	1 11.7	1 9; 8 19; 16 6; 23 16
U Cephei	0 53.4	+81 20	7.0— 9.0	2 11.8	5 8; 12 19; 20 7; 27 18
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	7 17; 13 20; 19 23; 26 2
TW Cassiop.	37.6	+65 19	8.2— 9.0	1 10.3	4 3; 11 6; 18 10; 25 13
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	2 1; 8 22; 22 16; 29 12
RZ Cassiop.	39.9	+69 13	6.9— 8.1	1 04.7	7 11; 14 15; 21 19; 28 23
TX Cassiop.	44.4	+62 22	9.4—10.1	2 22.2	4 9; 13 3; 21 22; 30 17
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	7 2; 15 1; 23 0; 30 22
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6	18 12
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	4 18; 10 12; 21 23; 27 16
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	7 9; 14 4; 20 23; 27 18
λ Tauri	55.1	+12 12	3.3— 4.2	3 22.9	1 16; 9 13; 17 11; 25 9
RW Tauri	3 57.8	+27 51	7.1—<11	2 18.5	7 6; 15 14; 23 21
RV Persei	4 04.2	+33 59	9.5—11.0	1 23.4	6 10; 14 8; 22 5; 30 3
RW Persei	13.3	+42 04	8.8—11.0	15 04.8	6 5; 19 10
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	7 11; 16 22; 26 8
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1	12 23; 25 9
TT Aurigae	5 02.8	+39 27	7.8— 8.7	0 16.0	3 8; 10 0; 23 8; 30 0
RY Aurigae	11.5	+38 13	10.7—11.7	2 17.5	4 0; 9 11; 20 8; 25 19
RZ Aurigae	42.9	+31 40	10.6—13.3	3 00.3	5 22; 11 22; 23 23; 30 0
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	8 14; 17 6; 25 22
Z Orionis	50.2	+13 40	9.7—10.7	5 04.9	7 23; 18 9; 23 19
SV Gemin.	54.6	+24 28	9.8—<11	4 00.2	3 14; 11 14; 19 14; 27 15
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	1 7; 7 1; 18 12; 29 23
U Columbae	6 11.2	−33 03	9.2—10.0	2 19.2	6 10; 12 0; 23 5; 28 19
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8	6 12; 14 17; 22 22
RW Monoc.	29.3	+ 8 54	9.0—10.8	1 21.7	5 2; 12 17; 20 8; 27 23
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0	7 2; 19 7
RU Monoc.	6 49.4	− 7 28	9.8—10.5	0 21.5	5 20; 13 0; 20 4; 27 8
R Can. Maj.	7 14.9	−16 12	5.8— 6.4	1 03.3	4 16; 13 18; 22 20
RY Gemin.	21.7	+15 52	8.9—<10	9 07.2	4 9; 13 17; 23 0
Y Camelop.	27.6	+76 17	9.5—12	3 07.3	11 17; 21 15; 31 13
TX Gemin.	30.3	+17 8	10.0—11.9	2 19.2	9 10; 17 20; 26 5
RR Puppis	43.5	−41 08	9.4—10.7	6 10.3	6 4; 12 15; 19 1; 25 11
V Puppis	7 55.4	−48 58	4.1— 4.8	1 10.9	5 22; 13 5; 20 11; 27 18
X Carinae	8 29.1	−58 53	7.9— 8.7	0 13.0	6 15; 14 18; 22 21; 30 23
S Cancri	8 38.2	+19 24	8.2—10	9 11.6	7 14; 17 2; 26 13
RX Hydrae	9 00.8	− 7 52	9.1—10.5	2 6.8	4 16; 13 19; 22 22
S Antliae	27.9	−28 11	6.7— 7.3	0 07.8	2 17; 9 4; 22 3; 28 15
S Velorum	29.4	−44 46	7.8— 9.3	5 22.4	5 0; 10 22; 22 19; 28 18
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	7 5; 15 15; 24 2
RR Velorum	10 17.8	−41 36	10.0—10.9	1 20.5	3 3; 12 10; 21 16; 30 23
SS Carinae	10 54.2	−61 23	12.2—12.8	3 07.2	4 11; 11 2; 24 7; 30 21
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	3 14; 12 10; 21 5; 30 0
RW Urs. Maj.	35.4	+52 34	10.3—11.4	7 07.9	2 8; 9 16; 16 23; 24 7
Z Draconis	11 39.8	+72 49	9.9—13.6	1 08.6	7 1; 13 19; 20 14; 27 9
RZ Centauri	12 55.6	−64 05	8.5— 8.9	1 21.0	5 7; 12 19; 20 8; 27 18
RS Can. Ven.	13 06.3	+36 28	7.5—12.5	4 19.2	2 3; 11 17; 21 7; 31 22

Minima of Variable Stars of Short Period—Continued.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1916 June
	h m	° ′		d h	d h d h d h d h
SS Centauri	13 07.2	−63 37	8.8—10.4	2 11.5	3 5; 10 16; 18 2; 25 13
δ Librae	14 55.6	− 8 07	4.8— 6.2	2 07.9	1 1; 8 1; 22 0; 28 23
U Coronae	15 14.1	+32 01	7.6— 8.7	3 10.9	6 20; 13 17; 20 15; 27 13
TW Draconis	32.4	+64 14	7.3— 8.9	2 19.4	4 19; 13 5; 21 15; 30 1
SS Librae	15 43.4	−15 14	9.3—11.5	0 18.4	2 5; 9 21; 17 13; 25 4
SW Ophiuchi	16 11.1	− 6 44	9.2—10.0	2 10.7	3 3; 10 11; 17 19; 25 3
SX Ophiuchi	12.6	− 6 25	10.5—11.2	2 01.5	4 17; 13 0; 21 6; 29 12
R Arae	31.1	−56 48	6.8— 7.9	4 10.2	1 21; 10 18; 19 14; 28 11
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1	2 8; 13 9; 23 2
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	4 5; 11 0; 17 20; 24 15
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	7 11; 15 20; 24 5
u Herculis	13.6	+33 12	4.6— 5.4	2 01.2	4 23; 11 2; 23 10; 29 13
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	7 1; 14 6; 21 11; 28 16
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	7 0; 14 9; 21 18; 29 3
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	8 3; 16 7; 24 12
TX Scorpii	48.6	−34 13	7.5— 8.2	0 22.6	5 0; 12 13; 20 1; 27 14
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	1 10; 9 3; 16 21; 24 15
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	4 23; 12 23; 20 22; 28 22
WX Sagittae	53.6	−17 24	9.2—10.8	2 03.1	5 22; 14 10; 22 22
WY Sagittae	17 54.9	−23 1	9.5—10.6	4 16.0	6 23; 16 7; 25 15
SX Draconis	18 03.0	+ 58 23	9.3—10.5	5 04.1	4 21; 15 5; 25 13
RS Sagittarii	11.0	−34 08	5.9— 6.3	2 10.0	1 11; 8 17; 23 5; 30 10
V Serpentis	11.1	−15 34	9.5—11.1	3 10.9	4 7; 11 4; 18 2; 25 0
RZ Scuti	21.1	− 9 15	7.4— 8.3	15 03.2	1 10; 16 13
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	5 23; 14 5; 22 11; 30 18
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	7 18; 16 16; 25 13
SX Sagittarii	39.7	−30 36	8.7— 9.8	2 01.8	7 5; 15 13; 23 20
RR Draconis	40.8	+62 34	9.3—13	2 19.9	3 12; 12 0; 20 12; 28 23
RS Scuti	43.7	−10 21	9.3—10.3	0 15.9	3 2; 9 17; 23 0; 29 16
β Lyrae	46.4	+33 15	3.4— 4.1	12 21.8	4 13; 17 11; 30 9
U Scuti	18 48.9	−12 44	9.1— 9.6	0 22.9	4 14; 14 3; 23 17
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	3 1; 10 15; 18 4; 25 18
RV Lyrae	12.5	+32 15	11. —12.8	3 14.4	5 17; 12 22; 20 3; 27 8
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	3 5; 12 4; 21 3; 30 2
U Sagittae	14.4	+19 26	6.5— 9.0	3 09.1	6 12; 13 6; 20 0; 26 19
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	5 3; 12 12; 19 20; 27 5
TT Lyrae	24.3	+41 30	9.3—11.6	5 05.8	2 19; 8 1; 18 13; 29 0
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	2 12; 9 0; 22 1; 28 14
SY Cygni	19 42.7	+32 28	10 —12	6 00.2	3 12; 9 12; 21 12; 27 12
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	7 7; 13 22; 20 12; 27 3
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	1 9; 10 12; 19 16; 28 19
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	4 1; 12 11; 20 21; 29 8
RW Capric.	12.2	−17 59	8.8—10.6	3 09.4	5 20; 12 15; 19 10; 26 5
UW Cygni	19.6	+42 55	10.5—10.8	3 13	3 17; 10 14; 17 12; 24 10
V Vulpec.	32.3	+26 15	8.2—9.8	37 19.0	6 19
W Delphini	33.1	+17 56	9.4—12.1	4 19.4	4 7; 13 21; 23 12
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	1 14; 10 18; 19 23
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	6 13; 14 0; 21 12; 29 0
WZ Cygni	49.3	+38 27	9.9—10.8	0 14.0	5 20; 11 16; 23 8; 29 5
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	9 16; 19 18; 29 21
VV Cygni	21 02.3	+45 23	12.1—13.8	1 11.4	7 7; 14 16; 22 1; 29 11
AE Cygni	09.0	+30 20	10.8—11.4	0 23.3	10 7; 19 23; 29 16
RY Aquarii	14.8	−11 14	8.8—10.4	1 23.2	7 23; 15 20; 23 17
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3	19 3
RT Lacertae	21 57.4	+43 24	9.1—10.5	5 01.7	2 7; 12 10; 22 14
RW Lacertae	22 40.6	+49 08	10.2—11.2	5 04.4	1 12; 6 18; 17 1; 27 10
X Lacertae	22 45.0	+55 54	8.2— 8.6	5 10.6	6 4; 11 14; 22 12; 27 22
TT Androm.	23 08.7	+45 36	11.3—12.6	2 18.3	8 2; 16 9; 24 16
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.4	2 21; 10 10; 17 22; 25 11
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	5 1; 13 7; 21 12; 29 18

Maxima of Variable Stars of Short Period.

[Calculated by Bertha Booth and Bessie Burnham at Goodsell Observatory.]

Given to the nearest hour in Greenwich mean time. To obtain Eastern standard time subtract 5^h; Central standard time 6^h; etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1916. June
	h m	° ′		d h	d h; d h; d h; d h
SX Cassiop.	0 05.5	+54 20	8.6— 9.4	36 13.7	5 6;
SY Cassiop.	0 09.8	+57 52	9.3— 9.9	4 1.7	6 0; 14 4; 22 7; 30 10
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	8 2; 15 20; 23 15
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2	13 22; 28 17
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	5 6; 13 5; 21 3; 29 2
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	2 16; 10 12; 18 7; 26 2
TU Persei	3 01.8	+52 49	11.4—12.2	0 14.6	3 20; 11 3; 18 9; 25 16
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0	12 28
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	5 4; 13 18; 22 8; 30 22
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	9 17; 20 20
RX Aurigae	4 54.5	+39 49	7.2— 8.1	11 15.0	9 11; 21 2
SX Aurigae	5 04.6	+42 02	8.0— 8.7	1 12.8	1 5; 8 21; 16 12; 24 4
SY Aurigae	05.5	+42 41	8.4— 9.5	10 03.3	1 10; 11 13; 22 17
Y Aurigae	21.5	+42 21	8.6— 9.6	3 20.6	1 5; 8 22; 16 15; 24 8
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	1 7; 12 8; 23 9; 28 22
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	6 7; 13 21; 21 10; 29 0
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3	17 19
RZ Camelop.	23.7	+67 06	11.0—13.0	0 11.5	1 23; 9 4; 23 14; 30 19
W Gemin.	29.2	+15 24	6.7— 7.5	7 22.0	1 3; 9 1; 16 23; 24 21
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	2 19; 12 23; 23 3
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5	12 7
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	3 15; 11 13; 19 12; 27 11
V Carinae	8 26.7	−59 47	7.4— 8.1	6 16.7	3 21; 10 14; 24 0; 30 16
T Velorum	8 34.4	−47 01	7.6— 8.5	4 15.3	1 15; 10 22; 20 4; 29 11
V Velorum	9 19.2	−55 32	7.5— 8.2	4 08.9	3 12; 12 6; 21 0; 29 18
Z Leonis	9 46.4	+27 22	7.9— 9.6	59 0.0	
RR Leonis	10 02.1	+24 29	9.1—10.1	0 10.9	5 1; 11 20; 18 15; 25 9
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	2 23; 9 14; 22 19; 29 9
S Muscae	12 07.4	−69 36	6.4— 7.3	9 15.8	1 12; 11 4; 20 20; 30 12
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7	6 12; 14 12; 22 11; 30 11
T Crucis	15.9	−61 44	6.8— 7.6	6 17.6	5 0; 11 18; 18 12; 25 4
R Crucis	18.1	−61 04	6.8— 7.9	5 19.8	6 4; 12 0; 23 15; 29 11
S Crucis	12 48.4	−57 53	6.5— 7.6	4 16.6	5 14; 14 23; 24 9; 29 1
W Virginis	13 20.9	− 2 52	8.7—10.4	17 06.5	17 22
SS Hydrae	25.0	−23 08	7.4— 8.1	8 4.8	4 14; 12 19; 21 0; 29 5
RV Urs. Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	5 20; 12 20; 19 21; 26 21
ST Virginis	14 22.5	− 0 27	10.3—11.4	0 09.9	2 0; 10 5; 18 11; 26 16
V Centauri	25.4	−56 27	6.4— 7.8	5 11.9	4 10; 9 22; 20 21; 26 9
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	5 5; 12 18; 20 7; 27 20
RU Bootis	14 41.5	+23 44	12.8—14.3	0 11.9	1 7; 8 17; 23 13; 30 23
R Triang. Austr.	15 10.8	−66 08	6.7— 7.4	3 09.3	5 18; 12 13; 19 8; 26 2
S Triang. Austr.	15 52.2	−63 29	6.4— 7.4	6 07.8	2 17; 9 1; 21 16; 28 0
S Normae	16 10.6	−57 39	6.6— 7.6	9 18.1	2 12; 12 6; 22 0
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	6 16; 15 12; 24 9
RV Scorpii	16 51.8	−33 27	6.7— 7.4	6 01.5	6 13; 12 15; 24 18; 30 19
X Sagittarii	17 41.3	−27 48	4.4— 5.0	7 00.3	7 1; 14 2; 21 2; 28 2
Y Ophiuchi	47.3	− 6 07	6.1— 6.5	17 02.9	6 4; 23 7
W Sagittarii	17 58.6	−29 35	4.3— 5.1	7 14.3	8 8; 15 22; 23 12
Y Sagittarii	18 15.5	−18 54	5.4— 6.2	5 18.6	2 13; 8 8; 19 21; 25 15
U Sagittarii	26.0	−19 12	6.5— 7.3	6 17.9	3 20; 10 14; 24 1; 30 19
Y Scuti	32.6	− 8 27	8.7— 9.2	10 08.3	10 4; 20 12; 30 20
Y Lyrae	34.2	+43 52	11.3—12.3	0 12.1	5 10; 11 11; 23 13; 29 13
RZ Lyrae	18 39.9	+32 42	9.9—11.2	0 12.3	5 22; 12 1; 24 8; 30 11

Maxima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1916. June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
RT Scuti	18 44.1	−10 30	9.1— 9.7	0 11.9	3 4;	9 2;	21 0;	26 22				
κ Pavonis	18 46.6	−67 22	3.8— 5.2	9 02.2	5 17;	14 20;	23 22					
U Aquilae	19 24.0	− 7 15	6.2— 6.9	7 00.6	7 6;	14 6;	21 7;	28 7				
XZ Cygni	30.4	+56 10	8.6— 9.3	0 11.2	7 5;	14 5;	21 5;	28 5				
U Vulpec.	32.2	+20 07	6.5— 7.6	7 23.5	8 5;	16 4;	24 4					
SU Cygni	40.8	+29 01	6.2— 7.0	3 20.3	2 6;	9 23;	17 15;	25 8				
η Aquilae	47.4	+ 0 45	3.7— 4.5	7 04.2	5 10;	12 15;	19 19;	26 23				
S Sagittae	51.5	+16 22	5.6— 6.4	8 09.2	6 17;	15 2;	23 11					
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	6 16;	13 0;	19 8;	25 15				
X Cygni	20 39.5	+35 14	6.0— 7.0	16 09.3	6 11;	22 20						
T Vulpec.	47.2	+27 52	5.5— 6.1	4 10.5	2 17;	11 14;	20 11;	29 8				
WY Cygni	52.3	+30 03	9.6—10.4	0 13.5	5 19;	12 12;	19 6;	25 23				
RV Capric.	55.9	−15 37	9.2—10.1	0 10.7	4 22;	11 15;	18 8;	25 1				
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4	3 23;	18 16						
VY Cygni	21 00.4	+39 34	8.8— 9.5	7 20.6	8 15;	16 12;	24 8					
SW Aquarii	10.2	− 0 20	9.9—10.8	0 11.0	1 2;	7 23;	21 18;	28 15				
VZ Cygni	21 47.7	+42 40	8.2— 9.2	4 20.7	5 19;	15 12;	25 6;	30 3				
Y Lacertae	22 05.2	+50 33	9.1— 9.6	4 07.8	9 4;	17 20;	26 11					
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	2 22;	13 16;	24 9;	29 18				
Z Lacertae	36.9	+56 18	8.2— 9.0	10 21.1	6 9;	17 6;	28 3					
RR Lacertae	37.5	+55 55	8.5— 9.2	6 10.1	5 17;	12 3;	18 13;	25 0				
V Lacertae	22 44.5	+55 48	8.5— 9.5	4 23.6	1 16;	11 15;	21 14;	26 13				
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	3 19;	9 6;	20 3;	25 13				
RS Cassiop.	32.6	+61 52	9.0—11.0	6 07.1	1 5;	7 12;	20 2;	26 10				
RY Cassiop.	47.2	+58 11	9.3—11.8	12 03.4	6 18;	18 21						
V Cephei	23 51.7	+82 38	6.0—7.0	0 23.6	1 9;	11 8;	21 8;	26 8				

New Variables near the South Pole.—The Harvard College Circular No. 191 gives the results of the study by Miss Leavitt of photographic plates of the region near the south pole for the purpose of discovering new variables. Nineteen new variables were found. All of these are faint and beyond the reach of any but the large telescopes visually. The variation in the brightness of these individual stars ranges from 0.6 magnitude to <4.0 magnitude.

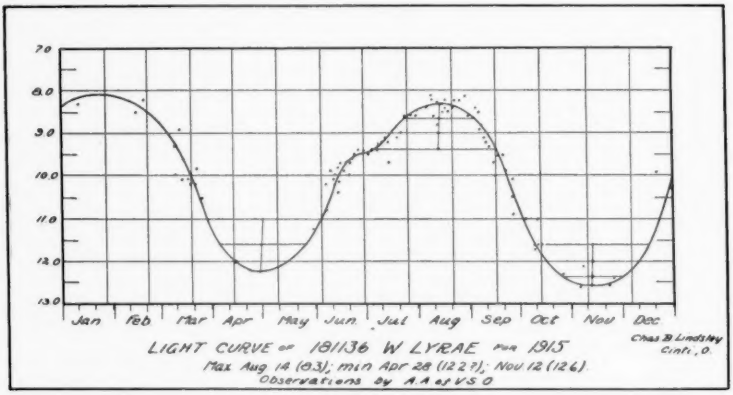
RR Lyrae and RT Aurigae.—In Laws Observatory Bulletins, Nos. 22 and 23, Dr. C. C. Kiess gives results of his study of these two variables.

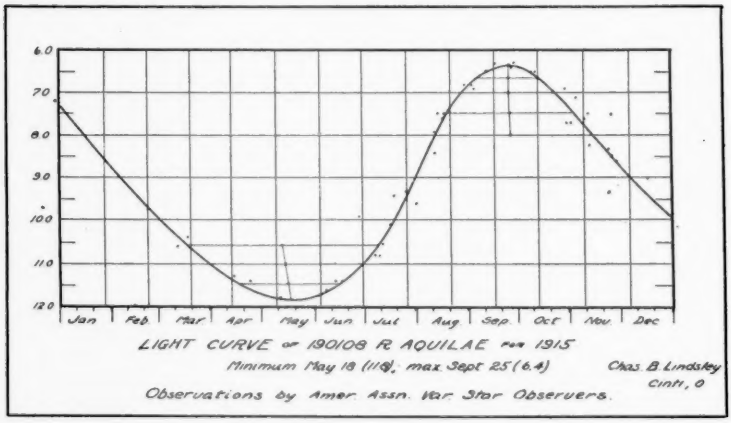
The first of these is found to vary approximately from the seventh magnitude to the eighth magnitude, the photographic range being slightly less than the visual range which is unusual. The period is short, a little more than a half a day.

For the latter star new elements are defined as follows:

$$\text{Max.} = \text{J. D. } 2417173.459 + 3^{d}.72806\ E.$$

These differ very slightly from those assigned to this star by Astbury who discovered this variable in 1905.





COMET AND ASTEROID NOTES.

Comet *a* 1916 (Neujmin).—The last two positions of this comet as given in the ephemeris in the Lick Observatory Bulletin No. 280 are given below, because they may reach our readers in time for use by them. They are:

		α			δ		
		h	m	s	°	′	″
Apr.	29.5	10	23	15	— 9	57	2
May	1.5	10	27	40	—10	25	6

It is seen that the comet is moing rapidly in a southeasterly direction. It is becoming fainter also, being only about one-third as bright as at the time of discovery. It is therefore at the dates given about 11.5 or 12.0 magnitude. According to the elements given it is due to arrive at perihelion again about five years from this time.

NOTES FOR OBSERVERS.

Monthly Report of the American Association of Variable Star Observers, Mar.-Apr., 1916.

During the past month observations of 153 variable stars of long period have been recorded by our members, a decided and gratifying advance over the record for the two previous months. A maximum of the variable 074922 U Geminorum was well observed the second week of March, and one of 213843 SS Cygni the third week of March was observed by Messrs. Burbeck, McAteer, and Pickering.

Dr. Edward Gray has accepted the position of surgeon on a Pacific coast line steamer. Mr. S. C. Hunter returns in May from a trip to Japan. Rev. T. C. H. Bouton will spend the month of April in Florida.

The following calculated dates of maxima occuring in May are cited from "The Companion to the Observatory":

May	1	213553	RU Cygni	May	9	*204405* T Aquarii
	3	081617	V Cancri		16	*170215* R Ophiuchi
	8	153378	S Urs. Min.		23	171401 Z Ophiuchi
	9	*121418*	R Corvi		28	115919 R Comae
	9	*151822*	RS Librae		29	162119 U Herculis
					29	164715 S Herculis

It has been suggested that we adopt the Julian Day designation of the date of our observations, as the Julian period has been adopted into variable star work by professionals in order to facilitate the combination of observations scattered over a long period of time. As this increases the value of the reports, which is our aim, this suggestion will be adopted, and the time of the observation in every case should be expressed in tenths of a day G. M. T. Will members kindly make a note of this change in the form of the lists submitted to the Harvard College Observatory and to the Secretary. We will also include in our published list in "POPULAR ASTRONOMY" the negative observations. Even these have a value, and should rightfully have a place in our reports. The following tables are published to facilitate the time and Julian Day conversions:

TABLE FOR CONVERTING STANDARD ASTRONOMICAL TIME TO GREENWICH MEAN TIME, WHEN THE TENTH OF THE DAY ONLY IS REQUIRED.

G.M.T Dec.	75th Mer. Eastern		90th Mer. Central		105th Mer. Mountain		120th Mer. Pacific		G.M.T. Dec.
d	h m	h m	h m	h m	h m	h m	h m	h m	d
0.4	3 25	5 48							0.4
0.5	5 49	8 12	4 49	7 12	3 49	6 12			0.5
0.6	8 13	10 36	7 13	9 36	6 13	8 36	5 13	7 36	0.6
0.7	10 37	13 00	9 37	12 00	8 37	11 00	7 37	10 00	0.7
0.8	13 01	15 24	12 01	14 24	11 01	13 25	10 01	12 24	0.8
0.9	15 25	17 48	14 25	16 48	13 25	15 48	12 25	14 48	0.9
1.0	17 49	20 12	16 49	19 12	15 49	18 12	14 49	17 12	1.0
1.1			19 31	21 36	18 13	20 36	17 13	19 36	1.1
1.2					20 37	23 00	19 37	22 00	1.2

Example:—Observations made on January 10, 1916, in the Mountain Belt, between 8:37 and 11:00 local standard time, would equal 0.7 day in G.M.T. and those made between 18:13 and 20:36 would equal 0.1 of the next astronomical day G.M.T. These, expressed in Julian day and tenths, would equal 2420873.7 and 2420874.1, respectively.

VARIABLE STAR OBSERVATIONS Mar.-Apr., 1916.

001046
X Androm.

Mo.	Day	Est	Obs.
3	1	9.7	Bu

001726
T Androm.

Mo.	Day	Est	Obs.
3	1	8.5	Bu

001755
T Cassiop.

Mo.	Day	Est	Obs.
3	11	8.4	R
	23	8.0	M
	25	8.2	R
	30	8.7	Nt
	30	8.4	S

004435
V Androm.

Mo.	Day	Est	Obs.
3	1	13.4	B

004958
W Cassiop.

Mo.	Day	Est	Obs.
3	5	10.6	L
	23	9.2	M
	31	9.5	Ba

012350
RZ Persei

Mo.	Day	Est	Obs.
3	11	10.0	Y

014958
X Cassiop.

Mo.	Day	Est	Obs.
3	11	9.8	Y
	21	10.0	Y

015354
U Persei

Mo.	Day	Est	Obs.
3	1	8.4	B
	1	8.2	Bu
	8	7.8	V
	25	8.8	Pi
	25	9.7	R
	26	8.8	Mu
	29	8.6	V

021024
R Arietis

Mo.	Day	Est	Obs.
3	1	8.6	Bu
	11	8.5	R
	26	8.0	Pi

021143
W Androm.

Mo.	Day	Est	Obs.
3	1	8.6	Bu

021403
o Ceti

Mo.	Day	Est	Obs.
3	2	5.3	L
	3	5.1	E

021558
S Persei

Mo.	Day	Est	Obs.
3	1	9.0	B
	1	8.8	Bu
	11	9.4	R
	31	9.0	Ba

023133
R Triang.

Mo.	Day	Est	Obs.
3	1	6.2	Bu

024356
W Persei

Mo.	Day	Est	Obs.
3	1	9.8	Bu
	11	10.1	R
	25	10.0	Pi
	31	9.2	Ba
4	2	10.0	O

030514
U Arietis

Mo.	Day	Est	Obs.
3	1	9.2	Bu
	11	8.8	Y

032043
Y Persei

Mo.	Day	Est	Obs.
3	1	9.5	B
	1	9.8	Bu
	11	10.4	R
	31	9.1	Ba

032335
R Persei

Mo.	Day	Est	Obs.
3	11	12.5	Y
	21	12.0	Y
	31	9.8	Ba

033362
U Camelop.

Mo.	Day	Est	Obs.
3	11	8.2	R
	31	7.2	Ba

035915
V Eridani

Mo.	Day	Est	Obs.
3	9	9.5	Pi

041619
T Tauri

Mo.	Day	Est	Obs.
3	3	10.4	M

042215
W Tauri

Mo.	Day	Est	Obs.
3	1	9.1	B
	1	9.3	Bu
	3	8.8	M
	11	9.5	O
	11	8.5	R
	23	9.8	Pi
	25	8.9	R
	25	9.6	O
	25	9.6	Ba
	26	9.6	Pi
	31	9.3	Ba
	31	9.3	B
	31	9.6	O
	31	9.5	Nt

043065
T Camelop.

Mo.	Day	Est	Obs.
3	1	9.2	Bu
	30	8.7	Pi
	31	8.5	Ba

043274
X Camelop.

Mo.	Day	Est	Obs.
3	1	9.5	Bu
	1	9.0	B
	2	9.3	L
	3	9.1	E
	5	9.3	L
	11	8.7	O
	11	8.4	Y
	23	8.8	O
	25	8.5	O
	26	8.2	O
	29	8.3	V
	30	8.2	O
	30	8.3	Pi
	31	8.2	O
	31	8.4	Ba
4	2	8.2	O
	5	8.2	O

043208
RX Tauri

Mo.	Day	Est	Obs.
3	3	12.0	E
	3	11.5	M

044617
V Tauri

Mo.	Day	Est	Obs.
3	1	13.7	B
	31	13.4	B

045307
R Orionis

Mo.	Day	Est	Obs.
3	1	10.0	Bu

045514
R Leporis

Mo.	Day	Est	Obs.
2	21	9.3	L
3	1	8.6	Bu
	1	9.5	L
	9	9.3	Pi
	11	8.7	B

050022
T Leporis

Mo.	Day	Est	Obs.
3	1	9.8	Bu

050003
V Orionis

Mo.	Day	Est	Obs.
3	3	11.3	M
	4	11.6	Pi

050953
R Aurigae

Mo.	Day	Est	Obs.
3	1	9.2	Bu
	3	8.9	E
	19	8.7	M
	25	8.5	Ba
	26	8.4	Pi

052034
S Aurigae

Mo.	Day	Est	Obs.
3	1	8.6	Bu
	19	9.0	M
	25	9.0	Ba

052404
S Orionis

Mo.	Day	Est	Obs.
3	1	11.0	Bu
	3	11.0	M
	31	12.5	Ba

053068
S Camelop.

Mo.	Day	Est	Obs.
3	11	9.9	Y

053005
T Orionis

Mo.	Day	Est	Obs.
2	21	9.3	L
3	1	10.0	Bu
	1	9.5	L
	3	10.4	M
	4	9.5	Pi
	25	10.2	Bu
	26	9.6	Nt
	31	10.4	Ba

054319
SU Tauri

Mo.	Day	Est	Obs.
3	1.6	9.7	Bu
	3.6	9.6	E
	4.7	9.6	E
	8	9.4	V
	8.5	9.5	E
	9.6	9.5	E
	18.7	9.5	E
	25	9.4	V
	25.6	9.2	Ba
	26.6	9.4	O
	29	9.5	V
	31.6	9.2	Nt
	31.6	9.2	Ba
4	2.5	9.4	O
	5.5	9.5	O

054920
U Orionis

Mo.	Day	Est	Obs.
3	3	10.2	E
	26	9.7	O
	31	10.0	Pi
4	2	9.7	O

054974
V Camelop.

Mo.	Day	Est	Obs.
3	1	10.7	Bu
	3	11.0	E
	4	11.1	E
	8	11.4	E
	9	11.3	E
	11	11.3	Y
	30	11.3	B
	30	11.8	Pi
	31	11.6	Ba

055353
Z Aurigae

Mo.	Day	Est	Obs.
3	1	9.8	Bu
	3	9.7	E
	19	9.4	M
	21	9.9	Y

Z Aurigae

Mo.	Day	Est	Obs.
3	25	9.6	Ba
	26	9.8	Pi
	26	9.6	Ba
	31	9.9	Nt

060450
X Aurigae

Mo.	Day	Est	Obs.
3	1	12.4	L
	4	12.3	E
	21	11.9	Y
	31	11.3	B

061647
V Aurigae

Mo.	Day	Est	Obs.
3	21	10.8	Y

061702
V Monoc.

Mo.	Day	Est	Obs.
3	1	9.3	Bu
	5	9.2	Pi

063159
U Lyncis

Mo.	Day	Est	Obs.
3	11	12.6	Y
	31	12.6	Ba

063558
S Lyncis

Mo.	Day	Est	Obs.
3	4	12.8	E
	11	12.4	Y
	31	12.8	Nt

064030
X Gemin.

Mo.	Day	Est	Obs.
3	4	12.3	E
	31	12.8	Ba

065111
Y Monoc.

Mo.	Day	Est	Obs.
3	4	12.7	E

065208
X Monoc.

Mo.	Day	Est	Obs.
2	21	7.8	L
3	5	7.0	L
	5	7.5	Pi
	31	7.3	Ba

065355
R Lyncis

Mo.	Day	Est	Obs.
3	31	8.0	Ba

070122a
R Gemin.

Mo.	Day	Est	Obs.
3	4	11.6	Pi
	8	11.8	E
	26	12.2	Nt

070122
TW Gemin.

Mo.	Day	Est	Obs.
3	4	8.2	Pi
	8	8.3	E
	26	8.0	Nt

VARIABLE STAR OBSERVATIONS Mar.-Apr., 1916—Continued.

070122b
Z Gemin.

Mo.	Day	Est.	Obs.
3	8	12.3	E
	26	12.4	Nt

070310
R Can. Min.

Mo.	Day	Est.	Obs.
3	5	10.4	L
	19	9.5	M
	26	9.8	O
	30	9.6	Pi
	31	9.0	Ba
4	5	9.4	O

072708
S Can. Min.

Mo.	Day	Est.	Obs.
3	2	9.0	Mu
	5	9.6	L
	5	9.5	Pi
	5	9.4	Mu
	7	9.6	M
	8	9.9	E
	10	10.1	Mu
	11	10.4	O
	21	10.2	Mu
	25	10.6	S
	25	10.0	Pi
	26	10.3	Mu
	30	10.2	Mu
	31	10.4	Ba

073508
U Can. Min.

Mo.	Day	Est.	Obs.
3	1	8.6	Bu
	2	9.2	L
	7	9.2	M
	11	9.3	O
	23	9.5	O
	30	9.5	Pi
	30	9.5	O
	31	9.2	B
	31	9.1	Ba
4	5	9.5	O

074323
T Gemin.

Mo.	Day	Est.	Obs.
3	26	13.6	Sp

074922
U Gemin.

Mo.	Day	Est.	Obs.
3	1.5	13.9	B
	8.6	8.8	V
	8.6	8.9	E
	9.6	9.5	Ba
	9.6	9.2	E
	10.6	9.2	Sp
	10.7	9.4	E
	11.5	9.3	O
	11.5	9.1	Pi
	11.6	9.8	B
	12.7	9.4	E
	18.7	12.3	E
	31.6	13.8	B

081112
R Cancri

Mo.	Day	Est.	Obs.
3	1	9.0	Bu
	5	8.9	L
	9	8.9	Pi
	25	8.8	O
	31	8.8	O
	31	8.5	Ba

081617
V Cancri

Mo.	Day	Est.	Obs.
3	1	8.2	Bu
	9	8.5	Pi
	25	8.6	O
	31	8.8	O
	31	8.7	Ba

082405
RT Hydrae

Mo.	Day	Est.	Obs.
3	1	8.1	L
	11	8.2	Bu
	24	8.0	Ho
	30	8.2	Pi
	30	8.6	M
	31	8.2	O
	31	8.2	Ba

084803
S Hydrae

Mo.	Day	Est.	Obs.
3	5	11.2	Pi
	11	10.9	B
	30	11.6	M
	31	11.6	Ba

085008
T Hydrae

Mo.	Day	Est.	Obs.
3	11	9.8	Bu
	31	11.5	Ba

085120
T Cancri

Mo.	Day	Est.	Obs.
3	1	9.8	L
	11	9.4	B
	11	9.8	Bu

090151
V Urs. Maj.

Mo.	Day	Est.	Obs.
3	1	10.5	L
	2	10.4	L
	5	10.4	L
	5	10.4	Mu
	8	10.4	V
	9	10.9	Sp
	10	10.5	Mu
	11	11.1	R
	21	10.3	Mu
	25	11.3	R
	26	10.2	Mu
	29	10.2	V
	30	10.0	Mu
	31	11.2	Pi
	31	10.1	Ba

090425
W Cancri

Mo.	Day	Est.	Obs.
3	30	12.6	Pi
	31	12.8	Ba

093014
X Hydrae

Mo.	Day	Est.	Obs.
3	5	8.6	Pi
	11	8.6	Bu
	31	9.2	Ba

093934
R Leo. Min.

Mo.	Day	Est.	Obs.
3	3	8.0	M
	5	7.9	Pi
	11	8.8	Bu
	30	8.8	S
	31	8.7	O
	31	8.2	Ba

094211
R Leonis

Mo.	Day	Est.	Obs.
3	3	8.4	E
	3	8.4	M
	5	8.7	Pi
	5	9.3	Mu
	5	9.0	L
	10	9.0	Ma
	10	8.9	Mu
	11	9.3	O
	11	9.3	Bu
	21	9.2	Mu
	23	9.6	O
	25	9.0	S
	26	9.3	Mu
	27	9.8	Pi
	30	9.2	Mu
	30	9.6	O
	31	8.6	Ba
4	5	9.9	O

094622
Y Hydrae

Mo.	Day	Est.	Obs.
3	5	6.8	Pi
	11	7.0	Bu
	24	6.2	Ho
	31	6.6	Ba

095421
V Leonis

Mo.	Day	Est.	Obs.
3	10	13.1	Sp

103212
U Hydrae

Mo.	Day	Est.	Obs.
3	11	6.2	Bu

103769
R Urs. Maj.

Mo.	Day	Est.	Obs.
3	3	10.3	M
	9	9.9	Ba
	11	10.0	O
	23	11.0	M
	23	11.0	Pi
	25	10.8	S

R Urs. Maj.

Mo.	Day	Est.	Obs.
3	30	11.2	M
	31	11.2	Pi
	31	10.7	Ba

104620
V Hydrae

Mo.	Day	Est.	Obs.
3	5	6.5	Pi
	24	6.3	Ho
	31	6.4	Ba

104814
W Leonis

Mo.	Day	Est.	Obs.
3	11	12.8	Y

115919
R Comae

Mo.	Day	Est.	Obs.
3	10	12.4	Sp

120012
SU Virginis

Mo.	Day	Est.	Obs.
3	25	10.8	Ba

120905
T Virginis

Mo.	Day	Est.	Obs.
3	10	10.3	Sp
	25	10.3	Ba
	26	10.1	Sp
	29	10.4	V

121418
R Corvi

Mo.	Day	Est.	Obs.
3	3	8.3	M
	24	7.0	Ho
	25	7.0	Ba

122001
SS Virginis

Mo.	Day	Est.	Obs.
3	25	7.9	Ba
	26	7.8	Sp

122532
T Can. Ven.

Mo.	Day	Est.	Obs.
3	5	10.7	Pi
	11	10.0	Y
	25	9.4	Ba
	31	10.0	M
4	2	9.7	O

122803
Y Virginis

Mo.	Day	Est.	Obs.
3	25	12.2	Sp

123160
T Urs. Maj.

Mo.	Day	Est.	Obs.
3	8	11.5	E
	10	12.5	Sp
	26	11.6	Nt
	30	11.8	Ba

123307
R Virginis

Mo.	Day	Est.	Obs.
3	10	10.1	Sp
	13	10.0	L
	25	10.5	S
	26	10.4	Sp
	30	10.3	Ba
	31	10.7	O

123459
RS Urs. Maj.

Mo.	Day	Est.	Obs.
3	30	13.7	Ba

123961
S Urs. Maj.

Mo.	Day	Est.	Obs.
3	2	8.6	L
	3	9.0	E
	3	8.9	M
	4	9.1	Pi
	8	9.0	E
	9	8.7	Ba
	10	8.7	Sp
	10	8.8	Ma
	11	9.2	O
	11	8.8	Bu
	19	9.2	M
	21	9.6	S
	23	9.3	M
	23	9.9	Pi
	25	8.7	Ba
	25	9.7	O
	26	10.3	Nt
	30	9.8	M
	30	9.8	Ba
4	2	10.0	O

124606
U Virginis

Mo.	Day	Est.	Obs.
3	25	9.3	S
	25	8.8	Ba

132422
R Hydrae

Mo.	Day	Est.	Obs.
3	13	7.6	L

132706
S Virginis

Mo.	Day	Est.	Obs.
3	3	9.0	M
	13	9.2	L
	30	9.6	Ba

134440
R Can. Ven.

Mo.	Day	Est.	Obs.
3	5	8.6	Pi
	11	8.8	Bu
	13	8.9	L
	17	8.7	M
	25	9.0	Ba
	30	9.1	S
	30	9.0	M
	30	9.2	O
	31	8.9	Ba
4	5	9.1	O

141567
U Urs. Min.

Mo.	Day	Est.	Obs.
3	5	9.1	Pi
	11	9.6	Bu
	25	10.2	Ba

141954
S Bootis

Mo.	Day	Est.	Obs.
3	25	12.0	Sp
	30	11.9	Ba

VARIABLE STAR OBSERVATIONS Mar.-Apr., 1916—Continued.

142205
RS Virginis

Mo.	Day	Est.	Obs.	
3	30	13.5	Ba	

142539
V Bootis

3	5	10.0	Pi	
	9	10.1	Sp	
	11	10.0	M	
	25	9.9	S	
	30	10.1	O	
	30	10.0	Ba	
4	5	9.8	O	

142584
R Camelop.

3	11	9.6	Bu	
	11	9.5	O	
	25	9.3	O	
	25	9.2	Sp	
	30	9.2	O	
4	2	9.1	O	
	5	9.0	O	

143227
R Bootis

3	30	11.9	Ba	

144918
U Bootis

3	9	10.6	Sp	
	17	9.9	M	
	29	10.3	V	
	30	10.1	Ba	

150605
Y Librae

3	13	9.5	L	
	30	10.5	Ba	

151520
S Librae

3	13	10.0	L	

151731
S Cor. Bor.

3	5	8.5	Pi	
	11	6.9	M	
	30	8.9	Ba	

151822
RS Librae

3	13	10.8	L	

153378
S Urs. Min.

3	5	10.2	Pi	
	10	9.4	Mu	
	11	9.5	B	
	19	8.7	M	
	26	9.5	Mu	
	30	9.5	Mu	
	30	9.8	M	
	31	9.6	Nt	

154428
R Cor. Bor.

3	5.6	6.2	L	
	5.7	6.0	Pi	
	11.8	6.0	M	
	13.7	6.0	L	
	23.6	6.1	Nt	
	25.6	5.9	Ba	
	25.6	6.1	Nt	
	25.7	6.0	Pi	
	26.6	6.2	Nt	
	28.6	6.2	Nt	
	29	6.2	Mu	
	29.7	5.7	V	
	30.6	6.0	O	
	30.7	5.8	Ba	
	31.6	6.1	Nt	
	31.6	5.8	Ba	
4	2.6	6.0	O	

154536
X Cor. Bor.

3	30	13.2	Ba	

154539
V Cor. Bor.

3	5	8.4	Pi	

154615
R Serpentis

3	4	9.0	E	
	30	7.2	Ba	

155847
X Herculis

3	23	7.1	Nt	
	26	6.8	Nt	
	31	6.9	Nt	

160021
Z Scorpii

3	10	9.6	M	

160118
R Herculis

3	25	9.3	Sp	
	29	9.3	V	
	30	9.6	Ba	

160210
U Serpentis

3	30	8.9	Ba	

160221
X Scorpii

3	10	10.8	M	

160519
W Scorpii

3	10	11.0	M	

160625
RU Herculis

3	30	11.3	Ba	

161138
W Cor. Bor.

3	30	12.5	Ba	

161122c
T Scorpii

3	10	11.2	M	

162112
V Ophiuchi

3	15	8.0	M	

162119
U Herculis

3	3	11.2	M	
	25	11.1	Pi	
	30	10.9	Ba	

162815
T Ophiuchi

3	15	8.8	M	

162807
SS Herculis

3	5	9.9	L	
	25	9.7	Pi	
	29	9.8	V	
	30	9.9	Ba	

163137
W Herculis

3	10	9.2	Sp	
	11	9.3	M	
	25	8.5	Sp	
	25	10.4	Pi	
	30	8.4	Ba	

163172
R Urs. Min.

3	3	10.2	E	
	5	10.2	Pi	
	10	9.5	E	
	26	9.2	Sp	
	30	9.4	M	

163266
R Draconis

3	25	7.7	S	
	25	7.1	Pi	
	30	7.5	M	
	30	7.0	Ba	

164055
S Draconis

3	10	8.4	M	

164319
RR Ophiuchi

3	15	9.5	M	

164715
S Herculis

3	25	7.2	Pi	
	30	6.6	Ba	

165631
RV Herculis

3	10	11.1	Sp	
	10	11.0	M	
	25	11.4	Sp	
	30	12.0	Ba	

170215
R Ophiuchi

3	10	8.1	M	

171401
Z Ophiuchi

3	30	7.9	V	

171723
RS Herculis

3	25	9.6	Sp	

172809
RS Ophiuchi

3	15	11.5	M	

175458
T Draconis

3	30	11.1	Pi	

180531
T Herculis

3	25	10.8	Pi	

180565
W Draconis

3	25	11.9	Pi	
	26	11.8	Sp	

181103
RY Ophiuchi

3	30	9.0	V	

181136
W Lyrae

3	10	8.3	M	
	26	8.5	Sp	
	30	9.3	M	
	30	9.2	Pi	

183308
X Ophiuchi

3	30	8.7	V	

184205
R Scuti

3	5.7	6.1	L	
	13.7	5.8	L	

184243
RW Lyrae

3	26	13.6	Sp	

190926
X Lyrae

3	10	8.7	M	
	30	9.0	M	

190967
U Draconis

3	10	11.4	M	

192928
TY Cygni

3	30	9.5	V	
	30	9.0	M	

193449
R Cygni

3	30	10.6	M	

193732
TT Cygni

3	30	8.8	M	

194048
RT Cygni

3	30	9.0	M	

194632
χ Cygni

3	5	7.0	L	
	30	8.6	M	
	25	8.2	Pi	

195849
Z Cygni

3	25	11.9	Pi	

200647
SV Cygni

3	25	8.9	Pi	
	30	8.4	M	

200938
RS Cygni

3	25	7.4	Pi	
	30	6.9	M	

201647
U Cygni

3	25	7.6	Pi	
	30	8.8	M	

202539
RW Cygni

3	30	8.9	M	

202946
SZ Cygni

3	30	10.3	M	

210868
T Cephei

3	2	8.7	L	
	25	9.1	S	
	26	9.4	Nt	

213244
W Cygni

2	21	5.8	L	
3	13	5.7	L	

213678
S Cephei

3	30	9.6	S	

213843
SS Cygni

2	21.3	11.5	L	
3	13.7	11.7	L	
	25.8	8.3	Pi	
	29.8	8.6	Bu	
	30.8	8.2	Pi	
	30.1	8.4	M	

235350
R Cassiop.

3	1	9.6	B	

No. of observations 536; No. of stars observed 153; No. of observers 17.

JULIAN DAY CALENDAR FOR 1916.

Month		Jul. Day	Month		Jul. Day	Month		Jul. Day
January	0	2420863	May	0	2420984	September	0	2421107
February	0	20894	June	0	21015	October	0	21137
March	0	20923	July	0	21045	November	0	21168
April	0	20954	August	0	21076	December	0	21198

To convert the calendar date to Julian Day, add to the value given for the zero (0) of each month, the day in question. Thus: January 10th, 1916 equals J. D. 2420873.

The following members contributed to this report:—Messrs. Bancroft Bouton, Burbeck, Eaton, Hoge, Lacchini, Mach, McAteer, Mundt, Nolte, Olcott Pickering, Richter, Spinney, Vrooman, Miss Swartz and Miss Young.

WILLIAM TYLER OLCOTT,
Corresponding Sec'y.

Norwich, Conn.
Apr. 10, 1916.

COMMUNICATIONS.

An Unusual Meteor.—I wish to report an observation of mine of a brilliant fire-ball about 7 p. m. 1916 April 1. It was one of the largest that I ever saw, was moving very slowly, and seemed to leave portions of its substance in its trail in the form of sparks. It came from an easterly direction and moved almost due west. It was moving so slowly that I could easily see its nucleus. When I first saw it its motion was such that I unconsciously leaned over in my saddle for fear of it striking me. I heard no explosions nor any other sound although I listened closely. I believe that when it vanished it was less than a mile from my position.

WM. H. CASSELL, M. D.

WYTHEVILLE, Va.

GENERAL NOTES.

Miss Anna D. Lewis of Mt. Holyoke College has been appointed professor of mathematics at the Kentucky College for women. (*The Am. Math. Monthly*, March 1916).

Professor M. G. Mittag-Leffler, the distinguished Swedish mathematician, and his wife, on his seventieth birthday, set aside their entire fortune for the foundation of an International Institute for pure mathematics. (*Science*, April 14, 1916).

Dr. R. G. Aitken, astronomer of Lick Observatory, gave the regular monthly lecture before the Stanford University Faculty Science Association on March 22, 1916, on the subject of "Binary Stars." (*Science*, Apr. 7, 1916).

Dr. John A. Brashear, president of the American Society for Mechanical Engineers, was given the doctorate of laws at the Charter Day exercises of the University of Pittsburgh on March 20. On the evening of that day, a dinner was held in honor of the late Samuel P. Langley, secretary of the Smithsonian Institution and previously director of the Allegheny Observatory. The speakers included Dr. John A. Brashear and Dr. J. W. Holland. (*Science*, Apr. 7, 1916).

The Meeting of the Astronomical Society of the Pacific was held on March 25, at the Students Observatory, Berkeley, when the following program was presented: "Comet *a* 1916 (Neujmin)," by Miss Jessica M. Young; "The Riefler Clock", by Professor R. T. Crawford; "On the Universality of the Law of Gravitation", by Professor A. O. Leuschner. (*Science*. Apr. 7, 1916).

Actual Time of Signals from the U.S. Naval Observatory, March, 1916.

Day	Time of signals Noon			Error	Time of signals 10:00 p.m.			Error	
	h	m	s		h	m	s		
1	12	0	0.00	.00	9	59	59.96	−.04	
2	11	59	59.91	−.09	9	59	59.89	−.11	
3	11	59	59.87	−.13	9	59	59.85	−.15	
4	11	59	59.99	−.01	10	0	0.03	+.03	
5	12	0	0.05	+.05	10	0	0.06	+.06	Sunday
6	12	0	0.10	+.10	10	0	0.09	+.09	
7	12	0	0.11	+.11	10	0	0.14	+.14	
8	12	0	0.10	+.10	10	0	0.10	+.10	
9	11	59	59.99	−.01	9	59	59.99	−.01	
10	12	0	0.00	.00	9	59	59.99	−.01	
11	11	59	59.98	−.02	10	0	0.01	+.01	
12	12	0	0.02	+.02	10	0	0.02	+.02	Sunday
13	12	0	0.01	+.01	10	0	0.00	.00	
14	11	59	59.99	−.01	9	59	59.99	−.01	
15	11	59	59.97	−.03	9	59	59.98	−.02	
16	12	0	0.01	+.01	9	59	59.98	−.02	
17	12	0	0.02	+.02	9	59	59.99	−.01	
18	11	59	59.99	−.01	9	59	59.99	−.01	
19	11	59	59.98	−.02	9	59	59.97	−.03	Sunday
20	12	0	0.01	+.01	10	0	0.01	+.01	
21	11	59	59.99	−.01	9	59	59.99	−.01	
22	11	59	59.98	−.02	9	59	59.98	−.02	
23	11	59	59.98	−.02	9	59	59.97	−.03	
24	12	0	0.00	.00	10	0	0.00	.00	
25	12	0	0.00	.00	10	0	0.00	.00	
26	11	59	59.99	−.01	10	0	0.01	+.01	Sunday
27	12	0	0.00	.00	10	0	0.01	+.01	
28	12	0	0.01	+.01	10	0	0.02	+.02	
29	12	0	0.01	+.01	10	0	0.03	+.03	
30	12	0	0.03	+.03	10	0	0.03	+.03	
31	12	0	0.02	+.02	10	0	0.04	+.04	

Maximum error: Mar. 3, −0.15 sec.

Constant to be added to above errors to give error of radio signals from

Arlington +0.02 sec.

Key West +0.27

J. A. HOOGEWERFF,
Captain U. S. Navy
Superintendent.

U. S. Naval Observatory,
Washington, D. C.
Apr. 8, 1916.

The Greatest Need of Astronomy.—The greatest present need of astronomy, the grandest science, is not more big telescopes and big observatories, but a more favorable public opinion. Never in the history of the world have astronomical appliances been so great as they are at present, and never before has general interest in astronomy been so limited. The subject has been banished from nearly every high school in the land. The days have passed when Sir Richard Proctor could deliver a popular astronomical lecture in a crowded hall. The announcement in almost any city in the United States that the most learned or the most eloquent astronomer in the world is to deliver such a lecture would not now attract the interest that it would have attracted twenty-five or fifty years ago. When one considers the wonderful progress that the science has made, and the money that has been devoted to it, this state of things is appalling. Even the private schools, which retained astronomy as a cultural topic longer than the public schools, have for the most part discontinued it. The recent organizations of Boy Scouts, Camp Fire Girls and Woodcraft Indians apparently feel the need of a little astronomical instruction, as they recognize the need of a few drops of vanilla in a big can of ice cream. One organization devoted to outdoor life requires its members to know Polaris and the Great Dipper, but limits the *requirement* to that. Ye gods, upon what meat doth this our Caesar feed that he is grown so puny! No meat has been fed to this great giant, astronomy, so far as is known to the general public. I have recently lectured before Teachers' Institutes and high schools in a large number of the leading cities of the United States, but from not one of the many of whom I have asked this simple question have I received an answer: "Which way is the moon moving in the sky? Is it north, south, east, west, or what other point of the compass?' Several persons have ventured to say that it is going west as they had seen it set in the west and rise in the east. One only needs to question a social assembly or a gathering of educated men, or any school, to ascertain not only how deep is the ignorance but also how little the real interest in the subject whose grandeur so appeals to astronomers. Even if such persons do know that it is Venus in the west and the Pole Star in the north, there is but little mental grasp of the significance of the fact. With the majority it means almost as much as to say, "An oak tree is on the north side of my lot, and a maple on the east." But the situation is improving and the purpose of this article is to point out the manner in which it may be improved more rapidly. I believe the time has come when every community should have its moderate sized observatory, not with a large telescope, but preferably with several small ones, and that no technical work should be attempted. The librarian of a popular local library does not devote himself to technical bibliography but to the assisting of the public. Such must be the new type of astronomer. These popular observatories should not be equipped with a dome. A dome is right for technical research, but absolutely useless to a crowd of visitors. I would build a square cornered building with an ordinary, sloping roof but I would build it twelve or eighteen feet wide and twenty-four or thirty-six feet long, with a skeleton framework of the same size, on which I would roll the roof that should be divided into two sections, one gliding one way and the other the other. By this method an unobstructed view of any part of the heavens may be obtained, and it is ideal for constellation work. Within this observatory I would have at least four telescopes but none more than a nine-inch aperture. The ideal equipment would be a five-inch, a six-inch, an eight-inch and a nine-inch. In small communities a six-inch and a four-inch would be satisfactory.

At Sound Beach, Connecticut, has recently been completed what I think is the first community observatory in the United States, and I also think the largest in

the United States with a roof completely removable. But a very big one is not required to justify so superlative a statement. Ours is only twelve by twelve feet and so far as I know the next largest with movable roof is considerably smaller, but it is found to be large enough for the students at the University of Pennsylvania, at Philadelphia.

For such an observatory, a solid cement foundation is essential. Our new one has a solid block twelve by twelve feet and five feet deep made by blasting the stones from a neighboring stone wall and filling in with cobbles set in cement. The telescope is a six inch on pillar mount, the last work of the late Carl A. R. Lundin of The Alvan Clark & Sons Corporation. The instrument was placed in position in October; Mr. Lundin died in November.

Money for this observatory came from all the country from Maine to California. It is therefore not strictly a community observatory as it should have been, but a national, popularizing institution. The total cost was about thirteen hundred dollars and the observatory contains every essential requisite; even some adornment of the grounds is included in the bill. For five thousand dollars a grand community observatory could be erected on this plan. The astronomical observatories of the United States have not even considered the question of really popularizing the subject, a charge that I make deliberately, and can prove by the present state of lack of popular interest. We continue to pile up tomes of technical information for the few, while thousands of business men and women, of schoolgirls and schoolboys have not the remotest notion of the difference between a planet and a star, and still fewer know or seem to care that one of the planets is surrounded by rings. Astronomical science has been allowed to become a failure in the general uplift of humanity. If those interested in the subject are wise, they will recognize and acknowledge this unpleasant fact, and will right about face to devote their energies to the establishing of observatories not restricted to the computing of the parallax of a star, or to the discovery of another spectroscopic binary. They will try to make clear to the general public some of the common place things of the heavens. I deliberately assert that every technical observatory in these United States is a failure and a farce, so far as instructing the community at large is concerned. The visitors go not to become acquainted with the heavens but to become acquainted with the observatory, to say that they have met such an astronomer, and that they have looked for about a minute and a half through the big telescope. That is a knowledge of the observatory, and extremely limited. It has not lifted in the slightest degree the shades of ignorance that obscure the heavens. The great observatory of Allegheny built by the citizens of Pittsburgh and Allegheny, at a cost of more than three hundred thousand dollars, is absolutely useless to those citizens, since the huge telescope, the lens of which costs thirty thousand dollars, has never been and never will be looked through by even one citizen of Pittsburgh or of Allegheny, because it is not adapted to visual observation; it is a photographic lens. The visitors to that big observatory still look through a small Alvan Clark glass, the same that Langley used more than half a century ago. I say this in no spirit of adverse criticism. I am glad that the Allegheny observatory exists. I am glad that it is devoting its energies to technical work. It is needed for such investigations. All speed to its work.

But what amuses me is that the people of Pittsburgh and Allegheny think that they have an observatory. They have nothing of the kind. The technical workers have an observatory. I sincerely hope they will keep it and make good use of it, but what am I pleading for is that those cities and every other city in the United States will establish an observatory that shall be for the people and not exclusively for the few that are skilled in technical research.

It was Henry David Thoreau who said that he became alarmed when he had walked a mile into a forest and did not enter it. Let us, lovers of astronomy, be alarmed when we think of the gigantic telescopes now being erected at Mount Wilson, California, and of the other great observatories, and seriously ask ourselves, have the people of the United States one single observatory that to them is really worth while? Yes, they have. For a year we labored, and struggled, and talked, and wrote, and begged our friends from Maine to California until we accumulated $1,052.43 to erect in the little town of Sound Beach, Connecticut, a sheet iron building twelve by twelve feet, with a telescope six inches in aperture, only six inches but big enough for the place and useful. Let this act as an exemplar to other and larger places that shall establish observatories to resuscitate the gasping, dying interest in popular astronomy. I believe the question asked by "The Monthly Evening Sky Map" and by a number of other publications, "What is the matter with astronomy?" is to be answered in only one way. The matter is with the astronomers; they are thinking too much of themselves and of the technicalities of the science. The final test of anything is the general public welfare, but a highly specialized interest, like a highly specialized double rose, is in danger of going out in what Dr. Morris calls "a blaze of glory." Nations have done that, families have done it, and beware or the science of astronomy will do it.

It is encouraging to know that the greatest popularizing philanthropist of the United States is awake to these facts. In the March number of the "Women's Home Companion," Andrew Carnegie asks, "What are among the best practical uses to which wealth may be put?" He places first, great universities; second, astronomical observatories completely equipped to carry forth our knowledge of the universe and our earthly relations to it. And although he has devoted millions of dollars to the establishing of popular libraries he modestly places such libraries third upon the list. But look out. Everybody knows that the force of an observatory and library should be centrifugal, but danger threatens in establishing more observatories lest the effect shall become centripetal.

EDWARD F. BIGELOW.

ArcAdia: Sound Beach, Connecticut.

The General Ignorance of Astronomy.

Venus, Jupiter, and the Zeppelins.

NOTE.—The following item translated by Dr. Clifford C. Crump from a paper by Camille Flammarion in *L' Astronomie* for March 1916 shows the lack of astronomical knowledge, lamented in the preceding paper by E. F. Bigelow, to be more or less general. [EDITORS].

"Since I published in the New York Herald a chart on which I marked with circles from west to east, the positions of the planets visible in our beautiful winter sky so handsomely starred, I have received the following letter:

"'We are here at Rouen, three zealous readers of the New York Herald, and also members of the "Societé Astronomique de France," we meet almost every day at the "Place Boieldieu" and we love to talk about astronomy. Not long since while looking at your celestial chart we saw at once that your numbers 1 and 2, at the side of the chart, and to the west, represented Venus and Jupiter, which were very near each other on the night of the thirteenth and fourteenth. They also represented, without doubt, the lights of the Zeppelin which alarmed our beautiful city of Rouen Saturday evening.

" 'In fact, the rumor was current here that this aeriel apparition had been seen to arrive from Harve, brilliant from the south west, without any one being able to distinguish its form or hear its motor. Many eyes followed this double lighted flyer down to the horizon: two lights, forward and aft, until it disappeared at eight fifteen in the western haze without having caused any damage, or having thrown a single bomb.

" 'The most amusing part of the story is that at Rouen the alarm was complete As soon as the "enemy's fires" had been noticed, a shot from the cannon was fired as a warning, the fireman patroled the streets shouting "On guard!", and an hour later "Back to your quarters." All the danger had passed: Venus and Jupiter had set before the eyes of the citizens of Rouen.'

"Since the beginning of the war, there has passed scarcely a month without our Bulletin having discovered analogous confusion, and notably for four months, thousands of ignorant people have taken Jupiter for a dirigible. The position of the double luminary on the south-west horizon, the time of its appearance and disappearance, the apparent path of this aerial ship with head-light (Venus) and aft-light (Jupiter), all contribute to show us that many people are living on our earth in utter ignorance of astronomy, without knowing where they are, and without surmising the marvels of the universe.

"They had at Rouen exactly the same talk as at Paris in the "Place de l'Etoile," "Place de la Concorde," at Montmartre, and in other places in France as we have already mentioned.

"Among a hundred citizens there is scarcely one who ever forms an idea of astronomic realities. The multitude have eyes which do not see. The Chaldean shepherds and the contemporaries of Homer lived better, in truth, than we, and in closer touch with nature. Where is progress?"

THE SPECTRUM.

In silence flowing through a flawless glass
As clear as diamond or supernal space,
A tide of countless sunbeams swiftly pass
And leaves behind not e'en a fading trace;
A warm, soft stream of strong, resplendent light
Pours through my crystal glass—lo! On yon wall
A gorgeous band appears—O splendid sight!—
Prismatic colors like a rainbow fall.

The slower red, the orange, yellow, green,
The blue, the indigo, swift violet,
Like messengers from bright King Sol, are seen
As beautiful as clouds when he has set.

More iridescent than Earth's jewels bright
Upon my wall there shines that spectrum's light!

CHARLES NEVERS HOLMES

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